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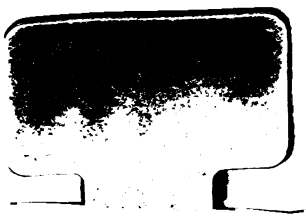
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STUDY OF COMPARATIVE PSYCHOLOGY,

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MDCCCLX.

189. b. 29.

"So work the honey-bees;
Creatures that, by a rule in Nature, teach
The art of order to a peopled kingdom.
They have a king, and officers of sorts,
Where some, like magistrates, correct at home;
Others, like merchants, venture trade abroad;
Others, like soldiers, armed in their stings,
Make boot upon the summer's velvet buds,
Which pillage they with merry march bring home
To the tent royal of their emperor;
Who, busied in his majesty, surveys
The singing masons building roofs of gold;
The civil citizens kneading up the honey;
The poor mechanic porters crowding in
Their heavy burdens at his narrow gate;
The sad-eyed justice, with his surly hum,
Delivering o'er to executors pale
The lazy yawning drone!"

SHAKSPEARE.



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TO

WILLIAM B. CARPENTER, ESQ.,

M.D., F.R.S., F.L.S., F.G.S., &c. &c.,

REGISTRAR OF THE UNIVERSITY OF LONDON,

AND AUTHOR OF

"HUMAN PHYSIOLOGY," "COMPARATIVE PHYSIOLOGY," AND MANY OTHER VALUABLE CONTRIBUTIONS TO OUR SCIENTIFIC LITERATURE,

THE FOLLOWING WORK

IS, WITH PERMISSION, RESPECTFULLY DEDICATED BY

THE AUTHOR.

PREFACE.

THE favour with which, owing to the daily increasing demand for popular scientific literature, the author's first publication was received, has encouraged him to make additional efforts, in the following pages, to convey to the reader accurate scientific information in easy and popular language; and although the work has no pretensions to erudition, yet it is to be hoped that some of the features described in connexion with the Bee's anatomy may prove new and interesting even to advanced students of Natural History. It is also right to remark that some inaccuracies which crept into the former work have been corrected in the present one; and in this portion of his labours the author has received considerable assistance from his scientific friends.

Dr. Hicks, whose aid is acknowledged on the title-page, supplied him with several valuable sketches,

and much useful information connected with the anatomy of the eyes, antennæ, and internal organs of the insect; and Mr. Tegetmeier, the esteemed Secretary of the Apiarian Society, provided him with several specimens of Bees, &c. &c., from the Society's collection of hives at Muswell Hill.

The assistance thus received, as well as that derived from Mr. Purkiss's excellent preparations and from those kindly lent to him by private friends, the author thinks it right to acknowledge before commencing his agreeable labours.

Liverpool, July 1860.

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ERRATA.

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„ 30, „ 6 from bottom, *for* antennæ *read* antenna.
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„ 47, last line but one, *for* fig. 20 *read* fig. 2, *o*.

THE

HONEY-BEE.

CHAPTER I.

INTRODUCTORY.

It would be paying but a poor compliment to those talented authors who have at various times sought to interest and instruct mankind through the publication of works on the natural history of the Common Hive-Bee, if we were to justify our selection of this insect as the subject of our second little Treatise on Humble Creatures, on the ground that we deemed it necessary for the purpose of rendering it familiar to the popular mind.

Hundreds of such works, including several of marked excellence, have been given to the world; but recent improvements in the microscope, and our daily increasing store of physiological knowledge, constantly lead to the revelation of new facts in regard to this and other insects, in addition to those already ascertained; and every day we find old and apparently

well-established theories fading away and giving place to others of a totally different character; so much so, that it may with justice be said that we are still engaged in studying the introduction to this branch of natural science.

The Bee, too, is peculiarly adapted not only for the investigation of insect anatomy, but also to aid in that of the progressive mental development of the animal races. Its structure, external as well as internal, is extremely beautiful and complicated, presenting numerous features, suited to its well-known habits of life, that are found in no other creature; and without reference to its wax- and honey-making properties, which render it especially interesting to man, we may add that its highly developed instinctive faculties, which constitute the moving spring of its various natural operations, cause it, in this respect, to hold the first rank in the invertebrate province of the Animal Kingdom; indeed some of its acts, if performed by man instead of by one of the lower animals, would be esteemed little short of miracles.

You may perhaps be disposed, reader, to regard this last assertion as somewhat exaggerated; but if you will accompany us in the consideration of a few of the phenomena of Bee-life, you will find that it is fully borne out by well-acknowledged facts.

Suppose yourself transported on board of one of those huge American steamers plying up and down the Mississippi, and that, falling short of provisions, you are some fine morning set on shore by the cap-

tain and told that there is a town somewhere a few miles distant, in which, if you can succeed in finding, you will be able to procure a meal, but that you must be sure to return by a certain hour, else the steamer will proceed on her course without you.

Picture to yourself the perplexity you would experience when you set foot upon the strange land, not knowing in which direction to turn in search of the locality that would have to be reached before your appetite could be appeased. In the absence of positive information you would probably seek some eminence from whence to survey the surrounding landscape, in order to trace, if possible, a road, or any other guide, to the desired goal.

If even you were so far successful, you would regard your position as a very awkward one, and would be apt to look upon the accomplishment of your journey within the prescribed period as little short of a miracle. But wonderful as it might appear in your case, in the Bee such a feat would be nothing unusual, and it is one that its instincts enable it to perform without the slightest difficulty. You have but to change the scene from the Mississippi to the Nile, and the society of human beings for a collection of inhabited bee-hives, and an opportunity will at once be presented for the consideration of one of the remarkable incidents in Bee-life. In Egypt, as well as in many other countries, including France, it is a common practice for Bee-owners, in whose vicinity there is not a sufficiently rich pasturage for their

winged flock, to entrust their hives to the care of boatmen who make a trade of transporting great numbers from place to place down the rivers, resting by day in order that the Bees may sally forth in search of honey, and continuing their course at night. The Bee accomplishes its object by means somewhat similar to those we suggested to yourself under the like circumstances, but with far greater accuracy and precision. No sooner does it quit the hive in the strange locality, than it mounts in the air, and having attained a sufficient eminence, flies off at once in the right direction, guided by its unerring instinct. This instinct also serves it on its return to the hive; and although it may not be permitted to sojourn in the same locality for two days together, yet it goes and comes apparently without any more difficulty or hesitation than we ourselves feel in departing from or returning to our homes during the performance of our daily duties. In this operation it is no doubt aided by its wonderful eyes, the beautiful structure of which we shall presently have an opportunity to examine, and then indeed you will no longer be surprised at the end that their possessor is thereby enabled to attain.

Remarkable as is this instinct in the Bee, which renders it capable of discovering its food at a distance, there is another phase in its history that is quite beyond our comprehension, and which appears almost supernatural when considered in relation to so insignificant and diminutive a creature.

You are of course well aware that in various stages of infancy the human being requires and receives a modification of his food, which becomes more solid as he advances in years; first he is provided with milk, then with farinaceous compounds, and finally with the ordinary food of an adult.

Smile not, reader, when we tell you that the young Bees (that is to say, the larvæ) are treated by their "nurses" very much after the same fashion.

In order to render this comprehensible, we shall have to enter into some of the details of the Bee's natural history; but as we shall, in so doing, touch upon two or three of its most interesting traits, we trust that no apology is necessary for dwelling on this part of the subject.

As you doubtless know, there are three varieties of Bees composing a hive; namely, a single *queen*, the mother of the hive; numerous *workers*, or unfruitful females; and the males, or *drones*. In speaking of the queen as the "mother" of the hive, we are borrowing a German expression, and a most appropriate one; for she deposits the eggs from which proceed all the inhabitants of the hive—workers, drones, and future queens, laying the ova in three distinct kinds of cells: those of the workers and drones are the ordinary hexagonal cells, varying a little in size; whilst the queen-eggs are placed in large oval ones, called royal cells, specially prepared by the worker-bees for their reception. (Pl. VIII. figs. 5 & 6.)

Here already, as a little reflection will show, we

have presented to us a number of strange phenomena. How do the workers know that the drone-cells must be constructed (as they are) of larger dimensions than the worker-cells, and that those intended for the reception of the young queens must be still larger and of a different shape? The eggs deposited by the queen, from which the three varieties proceed, are all alike in appearance; nay, those which produce queens and workers are precisely the same in every respect: *that* can therefore be no guide to the workers in the construction of the cells. Again, how does the queen know when and where to deposit each particular kind of egg?

"Instinct" will doubtless be your answer. Precisely so; and although we know but little in this respect, still we may be able to give you, farther on, some information on the subject that you will find new and interesting.

However, let us suppose the cells made, and the eggs deposited therein and hatched. The larvæ, or grubs, do not leave the cells, but are fed by a class of the worker community called by naturalists "Nurse-bees;" and how do you think they are nourished? First, in their earliest infancy, with honey, which we shall find hereafter to be a kind of food that has undergone a partial digestive process in the organs of the worker; then, as the days of the young ones increase in number, the sagacious nurses mix, and administer to them along with the honey, a quantity of bee-bread, consisting of the pollen of flowers, a

substance that afterwards serves as the food of the fully-developed Bee!

Thus you see that this "instinct" answers the same purpose, and leads to the same results in the Bee, as does reason in man.

But this is the least wonderful part of the story. The change of nourishment to which we have just referred also alters the very nature of the insects; for it is in consequence of their being thus fed, first on honey and then on a coarser food, that certain of the Bees (the greater proportion indeed) remain *workers*, their growth being stunted and the reproductive organs remaining undeveloped; whilst the queen is fed throughout her larvahood upon honey, or, as it is called by apiarists, royal paste. And, reader, *the Bees know this*: else, how is it, that, when they accidentally run short of a queen, they instantly seize upon a *worker*-larva and transfer it to a royal cell, hastily constructed for the purpose? This they actually do, and feed it upon royal paste during the remainder of its larval existence, until, instead of a worker-bee, they metamorphose the larva into a queen!

Instinct (a power or quality that we are unable clearly to define) is their guide in these and many other interesting operations; and if the psychical or mental endowments of the Bee are thus remarkable and perfect, equally so, both as regards their beauty and fitness for the end to be attained, shall we find the various organs and members with which the little

insect has been furnished. Take for example the eyes that guide it in its flight to the distant pasturage in search of honey, and which enable it to seek out the appropriate cell in which to store the liquid treasure on its return to the dark recesses of the hive.

The South American Condor soars up as high again as the highest peak of the Andes—ten miles above the level of the sea, until it assumes in the eyes of the beholder the appearance of a mere speck. This feathered denizen of the air possesses only one pair of eyes, and yet, we are told, its vision is so powerful, that, when it is elevated to this height, it embraces an area equal to that of the whole of Germany, and can detect, and launch itself directly upon, any mass of carrion in the plains below. What wonder then that the little Bee, provided as it is with some thousands of perfect organs of vision, varying in power and range, should rise up high in the air, and then fly off in a direct line to distant flower-beds, or with equal precision return to its habitation laden with pollen and honey!

Again, you will not be surprised to hear that the creature whose whole life is spent in collecting these last-named materials, should be furnished with internal as well as external receptacles wherein to store and convey home its precious treasures; but when you come to investigate their structure, and see how perfectly they are adapted to their respective uses, you will certainly be astonished to find how amply

even this humble little insect has been provided with contrivances necessary for the fulfilment of its task in creation. The same observation applies also to those instruments situated at the mouth, that aid it in the construction of its honeycomb. There you will discover powerful toothed shears (Pl. V. fig. 1, *b b*) for clipping and sawing, as well as trowel-shaped blades (Pl. V. fig. 1, *c c*) for plastering and moulding the wax and propolis; and in these operations it is also assisted by the long delicate tongue (Pl. V. fig. 1, *d d*), wherewith it rolls the thin riband-like bands of wax that serve it in the construction of its cell-walls: nor must we forget those remarkable claw-shaped pincers (Pl. VI. figs. 1, *e*, & 3), situated upon the extremity of its feet, with which it manipulates the various materials needed in its industrial occupations. Thus you see that the experienced little artisan is provided with every implement requisite for the prosecution of its calling, and for the performance of what we shall hereafter find to be no easy task.

Having thus drawn your attention to a few points of interest connected with the habits and structure of the Bee, we shall conclude these brief introductory remarks by referring to a phenomenon in its history to which we find no parallel in nature; and this time, reader, you may arm yourself with an ample stock of scepticism.

Suppose we were to place in your hand the newly-laid egg of a fowl, and to put the question, "Will the chick that is to be hatched from this egg be a

cock or a hen?" would you not laugh at the absurd inquiry, supposing that you believed it to be serious? Yet, if we are to credit the testimony of Professor Siebold—one of the first physiologists of the day,—accepted and endorsed by the opinion of our own great anatomist Professor Owen, and others, such an inquiry would be perfectly rational, were we to substitute the egg of a Bee for that of a hen. For we are told that by the aid of the microscope it is possible to distinguish in a fresh-laid Bee's egg such phenomena as will easily enable the observer to determine whether the larva that would have been produced would be a drone or a worker (we say *would have been*, because the experiment necessitates that the yolk should be expressed),—in other words, *to determine* whether it would have been a male or a female.

Now this is only one of a series of recent discoveries that have invested the history of the Bee with great additional interest, and these various phenomena we shall endeavour in the succeeding Chapters to render as clear and explicit as possible. Meanwhile, as there is, no doubt, somewhere within your reach a peopled hive, whatever may be the locality in which you reside, we would advise you to provide yourself with a few specimens of the insect, so that you may be able to examine the various parts as we describe them, and thus derive additional pleasure from the investigation.

CHAPTER II.

THE INSECT RACES AND THEIR CHARACTERISTIC ATTRIBUTES.—THE BEE'S PLACE IN THE ANIMAL KINGDOM.—GENERAL APPEARANCE AND PECULIARITIES OF THE WORKER, DRONE, AND QUEEN.—HEAD OF THE BEE.—WONDERFUL STRUCTURE OF ITS EYES.—THE OCELLI, OR COMPOUND EYES.—STEMMATA, OR SIMPLE EYES.—LESSONS CONVEYED BY THEIR EXAMINATION.

It is now so well understood what an insect *is*, as well as what it is *not* (for a great number of those forms that were popularly termed insects really belong to other divisions of the Animal Kingdom), that it would hardly appear necessary to refer at any length to the various attributes that characterize the class. We shall, however, glance cursorily at its typical features, leaving those who desire a more particular account of it, to consult one of the numerous zoological works that treat upon the subject.

An insect is an *articulated animal*; that is, an animal not possessing an internal skeleton, but enveloped in a thick integument or case composed of a number of articulations or rings connected together by a thinner membrane. When fully developed, it invariably possesses six annulated legs, whereby it is distinguishable from all other articulated animals;

for the Arachnidæ, or spider tribes, are furnished with eight; the Crustacea, or crab-like races, usually with ten; and the Myriapoda, or millipedes, with an indefinite number of these members.

With its six legs, constructed for progression on *terra firma* or in the water, there are coupled, as a general rule, one or two pairs of wings for flight in the air: and we may here observe, that in order that the body may be rendered lighter whilst moving in this element, the insect races do not breathe, as we do, by means of lungs, but are provided internally with numerous tubes and receptacles, of various dimensions, termed tracheæ, in which the air freely circulates, diminishing the specific gravity of the trunk.

Insects are furthermore rendered conspicuous by their antennæ or feelers, of which they possess a single pair, situated in front of the head, and composed of a series of rings or joints, in conformity with the structure of the rest of the body. These feelers serve to aid them in their numerous instinctive actions.

Lastly, the insect races usually undergo a more or less complete metamorphosis before arriving at the perfect state. In some cases they pass from one stage to the other without any marked change in their external appearance; in others, however, as in the Bee, they are subjected to a complete transition from the *vermiform* or worm-shaped grub or *larva* to the winged insect or *imago*, and spend a portion of their lives intermediate between these two stages in a quiescent, and apparently a lifeless state, enclosed

in a tough and hermetically sealed case: this period of their existence is known as the *pupa* or *chrysalis* state.

This metamorphosis, so well exemplified in the common Butterfly, is perhaps the most remarkable phenomenon in animated nature; and it has been compared by the poetic mind of Rogers to the final transition that takes place in ourselves when our soul wings its upward flight to heaven. He has expressed himself in language so sublime, that we cannot refrain from introducing his verses, which will serve to relieve the monotony of our physiological studies:—

"Child of the Sun! pursue thy rapturous flight,
Mingling with her thou lov'st in fields of light;
And where the flowers of paradise unfold,
Quaff fragrant nectar from their cups of gold.
There shall thy wings, rich as an evening sky,
Expand and shut with silent ecstasy.
Yet thou wert once a worm, a thing that crept
On the bare earth, then wrought a tomb and slept!
And such is man,—soon from his cell of clay
To burst a seraph in the blaze of day!"

The animals called *Insecta,* or insects, then, are characterized by the possession of a horny external case or envelope composed of rings, and are furnished with three pairs of articulated legs, one pair of articulated feelers, and usually one or two pairs of wings, whilst their life-history is marked by a more or less complete transition from the imperfect or larval to the perfect or imago form.

Let us now glance rapidly at the classification of the

insect races, and seek that group to which our common Hive-Bee belongs. The division of the Class by naturalists into *subclasses* and *orders* has been effected, first, by a reference to the degree of metamorphosis that the group undergoes; and, secondly, to the absence or presence of wings, and, where these are present, to their number and character.

Thus, one group or subclass that undergoes *no* apparent change is called *A*metabola; a second, in which the metamorphosis, though perceptible, is not complete, *Hemi*metabola; and the third, or highest subdivision, in which there is a complete transition from the worm-like or larval state, first to the pupal or motionless stage, and next to the imago or perfect insect, when the actual metamorphosis is effected, and the creature bursts forth from its tomb, fully fitted, both internally and externally, for its aërial existence:—this subclass is called *Holo*metabola; and here we shall find our Honey-Bee, along with the Beetle, Fly, and many other insects.

On examining the wings of the Bee, we shall perceive them to be four in number (Pl. II. fig. 1): but this is not a sufficiently unique feature in its organization to enable us to determine the *Order* to which it appertains; for there are several other orders, of widely different types, such as the Coleoptera (Beetles), Lepidoptera (Butterflies), &c., all of which possess two pairs of wings. We must look therefore at the *character* of the wings themselves, and shall find them to be of a firm, parchment-like texture hence it is that

the Order has received its name, *Hymenoptera,* from two Greek words, denoting the membranous structure of these organs. To this Order belongs not only the Bee, but also the Wasp, the Ant, and some other insects, all remarkable for their highly developed instinct. These minor groups are termed *families;* and that which includes the Bee is the family of *Apidæ,* or true Bees,—the Honey- or Hive-Bee being scientifically known as *Apis mellifica.*

The former designation (*Apis*) is that of its *genus,* and the latter (*mellifica*) of its species; but although its specific name is derived from a Latin word denoting its honey-making properties, it is not because it is the only species of Bee that produces this delicious substance (for there are others possessing the same attribute), but it is because to *us* its hive-labours render it par excellence *the* Honey-Bee. Once more, then, *Apis mellifica,* the Honey-Bee, belongs to the *family Apidæ,* or true Bees, included in the *Hymenopterous* (membranous-winged) *order,* of the *class Insecta* or insects, and in that *subdivision* of the Class known as *Metabola* or *Holometabola,* in consequence of the contained forms undergoing a complete metamorphosis; whilst (to complete our classification) the Insecta themselves occupy the highest rank as a *class* in that *province* of the Animal Kingdom known as the *Articulata* or *Arthropoda* (articulated feet), which are in their turn included in the great *subkingdom* of *Invertebrata,* or animals *not* possessed of an internal vertebrated skeleton.

Having thus acquitted ourselves of our obligations in the cause of systematic Zoology, and traced the correct position of our little Hive-Bee in the Animal Kingdom, let us now proceed to the less formal and more agreeable task of examining our subject with the aid of the lens, and endeavour to form a nearer acquaintance with its beautifully constructed organs and members. As there are three different kinds of inhabitants in a hive—the queen or perfect female, the drones or males, and the workers or partially developed females,—you might perhaps be puzzled which to select for investigation; for although they resemble one another to a great extent, yet each has its marked peculiarities. Inasmuch, however, as the worker is the most easily obtainable, and possesses some interesting features in its external anatomy that are wanting in the queen and drone, we shall choose it as the more immediate object of our study, and, as we proceed in its investigation, shall refer cursorily to the diversities of structure presented by the two last-named types.

In considering with the naked eye the general appearance of the worker-Bee (Pl. II. fig. 1), we cannot fail at once to notice that, in common with nearly all insects, its body is divided into three distinct parts or sections—the head (*a*), the thorax or chest (*b*), and the abdomen (*c*), which appear to be connected together as though they were strung upon a thread; and a very slight scrutiny will suffice to show that nearly all the members or appendages of the body are disposed on

PLATE II.

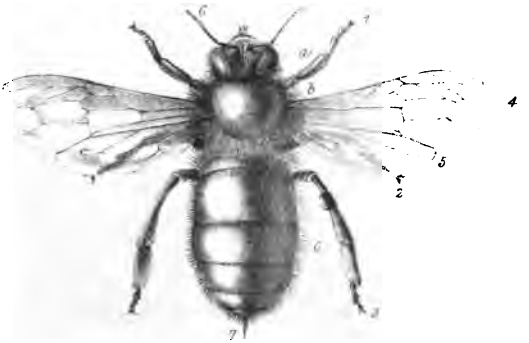


Fig. 1.

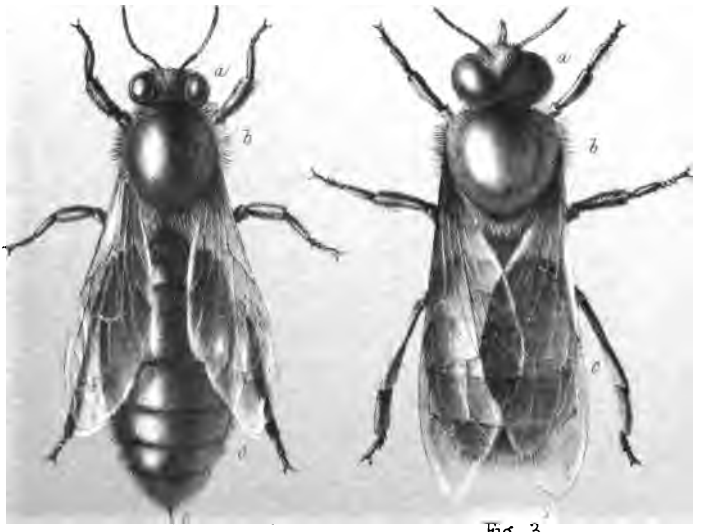


Fig. 2.

Fig. 3.

James Samuelson del.

J. H. Ford, lith.

Worker, Queen. & Drone of Honey Bee.

John Van Voorst, London

the middle or thoracic region. On the under side of this section we find the three pairs of legs (1, 2, 3)*, and on the dorsal surface the two pairs of wings (4, 5). The only prominent members, or rather organs, visible upon the head, are the delicate antennæ or feelers (6); whilst the posterior or abdominal segment appears perfectly free from all appendages, unless the sting (7) happen to be protruded.

And now as to the form and composition of the three sections themselves. In order to consider these, we will ask you to lay the insect on the palm of your hand, so that the dorsal surface, or back, is opposite you, as shown in the illustration (Pl. II. fig. 1). You will then perceive that the head presents an irregular flattened oval appearance, and is placed horizontally upon the thorax, which is nearly circular; whilst the posterior or abdominal segment, comprising at least half of the body, is of an elongated oval form, and distinctly divided into what appears to be perfect rings or articulations. But now reverse the position of the insect, so that the back is in contact with your palm, and you will at once observe that the rings of the abdomen are not perfect and continuous (Pl. III. figs. 2 & 3), but are composed of two rows of belts, a dorsal and a ventral series. The former or dorsal belts are by far the longest, reaching a little way round the body on either side, and overlying the ventral series, as shown

* The posterior legs APPEAR in the Plate as though they were appended to the hinder segment, but this arises from the direction that they take; they are attached to the chest.

in Pl. III. fig. 3, which represents an under view, and in fig. 2, the lateral view of the abdominal segment; and this overlapping of the dorsal belts gives to them, when viewed from above, the appearance of perfect rings. The ventral belts are not so regularly curved as the others, but form a figure somewhat resembling a breastplate with an obtuse angle in front (Pl. III. fig. 3). Not only do the dorsal rings overlie the ventral ones, but they (as well as the latter) overlie one another like the tiles on the roof of a house, and so the whole abdomen is enclosed in an almost impenetrable coat of mail,—an armature, however, that we shall find hereafter is not invulnerable to the terrible sting of the enemy.

The under-sides of the head and thorax are so covered with hairs, and the latter by the members of locomotion, that it is impossible to distinguish with the naked eye the peculiarities presented by the surface. But let us now see in what respect the general form of the worker differs from that of the queen and drone.

Both the latter are of larger dimensions than the worker, the queen (Pl. II. fig. 2) being considerably longer, and the drone (Pl. II. fig. 3) both longer and stouter. On comparing the *heads* of the three kinds, it will be found that those of the worker and queen closely resemble one another both in size and shape, whilst that of the drone is much increased in dimensions by its enormous oval compound eyes, which meet on the back of the head. The *thorax* of the

queen is longer and more oval than that of the worker, whilst that of the drone is shield-shaped. But the *abdomen* is the part of the body which presents in the three types the greatest dissimilarity: in the worker it is small and oval, in the queen much longer and thicker, tapering to a point, whilst that of the drone is short, stout, and oblong in shape, being fringed at the posterior part with long stout hairs (Pl. II. figs. 1, 2, 3). The prominent characteristics of the three varieties are: 1st, in the *drone*, the thickset body, covered all over with long hairs, especially at the termination of the abdomen, and the large oval eyes, meeting on the back of the head; 2nd, in the queen, the long, pointed abdomen and comparatively shorter wings; 3rd, in the worker, the smaller size of the insect, globular thorax, and the absence of those peculiarities which characterize the queen and drone*.

Let us now return to the consideration of the worker; and we shall ask you once more to change its position, and, viewing it in front, to obtain a survey of its physiognomy.

If you regard it in this aspect, aided we will say by a magnifying lens of about 10 or 20 diameters, you will find that the head of the worker-Bee closely resembles a card heart in shape (Pl. III. fig. 1); in the bulging sides of which (fig. 1, *a*) you will probably recognize its crescent-shaped *compound eyes*, whilst

* A detailed description of the three varieties will be found in Messrs. Kirby and Spence's work on Entomology, p. 358, note. (Cheap Edition.)

between these you will, on removing a few of the hairs, at once detect the *three simple eyes* (*b*, *b*), so disposed as to form a triangle with the apex or point downwards, and each consisting of a single bright lens.

From the apex of the inverted triangle, that is to say, from the lowest of the three simple eyes, a furrow proceeds downwards, terminating about the middle of the face, or rather branching off at that point into two similar indentations that are continued obliquely downwards until they reach either side of the face, so that the whole presents a forked appearance (Pl. V. fig. 1).

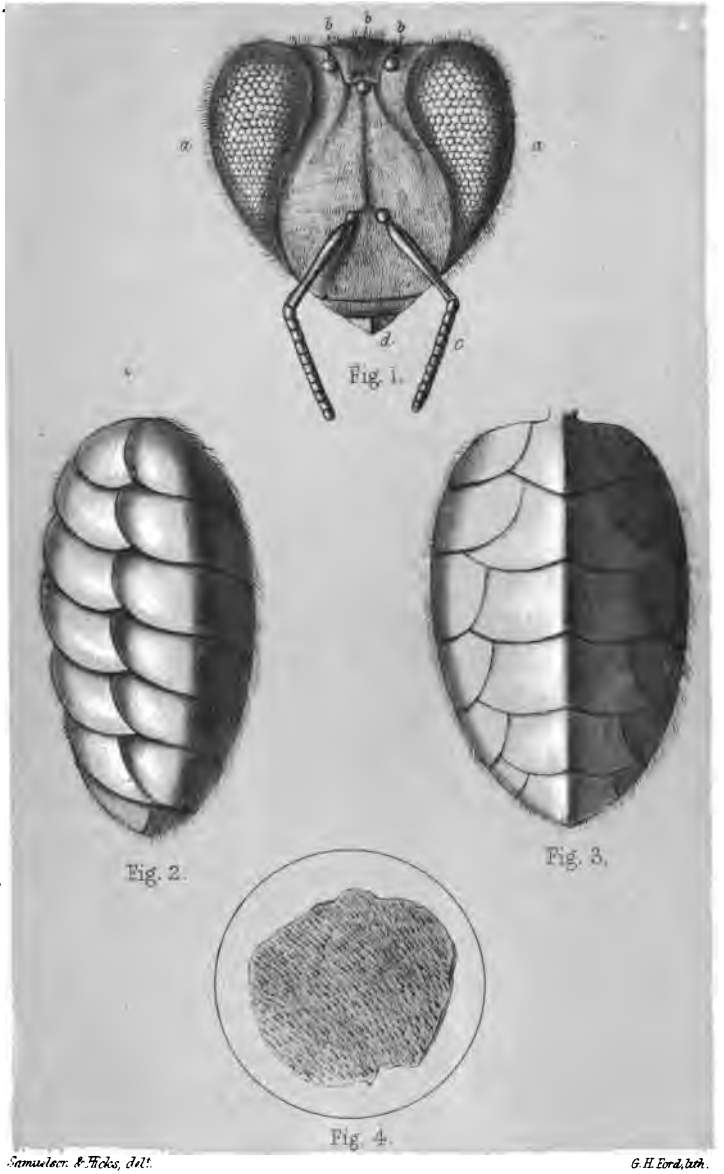
At the junction of these furrows the *antennæ* or feelers take root, one on each side of the medial line (Pl. III. fig. 1, *c*).

These organs appear to the naked eye like two short fragments of dark thread bent to a knee about the middle; and they are, as before remarked, the only visible external appendage to the head. The point of the head, however, will be seen, on closer examination, to be split like the nibs of a pen (Pl. III. fig. 1, *d*), and this we shall presently find to be the external part of the oral apparatus or mouth.

But let us now descend to a more minute investigation of these various organs of sense connected with the head of the Bee, commencing with its prominent compound eyes.

The object in nature that occurs to us as most nearly approximating the eye of the worker-Bee in

PLATE III.



Samuelson & Hicks, del.

G.H. Ford, lith.

Head, Abdomen, & Gastric Teeth of Worker.

John Van Voorst, London.

shape and appearance, is one of the leaves of chaff that surround a grain of wheat. It is of an elongated form—not oval, but pointed at one end; and the similarity between the two objects goes still farther, for both have a bright external appearance. But here the resemblance ends; and what a contrast is revealed by an examination of the two objects under the microscope!

The piece of chaff presents a uniform glazed surface, whilst in the eye of the Bee, which is much darker in colour, the brightness referred to arises from its peculiar structure; in fact, it is owing to the presence of about 3500 small but perfect hexagonal lenses fitting closely together, and disposed in regular rows over the whole circumference.

You will not be surprised, after this statement, to hear that the compound eye of a Bee is one of the most exquisitely constructed instruments in nature (we are almost tempted to say *the* most exquisite), and one which, small though it be, displays the power and wisdom of the Omnipotent in as striking a manner as do His most imposing and majestic works.

Let us therefore solicit your careful attention, whilst we endeavour to describe the details of its wonderful structure; and we can promise that you will be well requited for the trouble of accompanying us in the investigation.

In order to afford some idea of the general character and operation of one of these compound eyes, we

shall compare it to a bundle of telescopes (3500, remember!), so grouped together that the large terminal lenses present an extensive convex surface, whilst, in consequence of the decreasing diameter of the instruments, their narrow ends meet and form a smaller concentric curve. Now, if you can imagine it possible to look through all these telescopes at one glance, obtaining a similar effect to that of the stereoscope, you will be able to form some conception of what is probably the operation of vision in the Bee. This comparison, however, presents but a crude and imperfect idea of the organ in question, and we shall now accurately describe one of these "telescopes," as we have popularly termed them.

Each of the eyelets or "*ocelli*," which, aggregated, constitute the compound eye of a Bee, is itself a perfect instrument of vision, consisting of two remarkably formed lenses, namely an outer "*corneal*" lens (Pl. IV. fig. 1, *a a a*), and an inner or "conical" lens (*b*). The "corneal" lens (*a*) is a hexahedral or six-sided prism, and it is the assemblage of these prisms that forms what is called the "*cornea*" of the compound eye.

This "*cornea*" may easily be peeled off, and if the whole, or a portion, be placed under the microscope, the grouping of the beautiful lenses becomes distinctly visible. In Pl. IV. fig. 2, which represents a portion of the cornea magnified, a little of the subjacent layer of colouring-matter (*pigmentum nigrum*), of which we shall speak hereafter, has also been re-

tained, and is distinguishable behind some of the lenses.

But, stay! we must not yet part company with the corneal lens of the Bee's eyelet; for, on closer investigation, we shall perceive that it is not a *simple*, but a *compound* lens,—a fact of considerable importance, that has, we believe, been overlooked by physiologists. It is composed of two plano-convex lenses (Pl. IV. fig. 1, *l* 1, *l* 2) (that is, as you doubtless know, lenses having a plane and a convex surface) of different densities or refracting powers, and the plane surfaces of these lenses being adherent, it follows that *the prismatic corneal lens is a compound double convex lens**.

The effect of this arrangement is, that if there should be any aberration or divergence of the rays of light during their passage through one portion of the lens, it is rectified in its transit through the other. Now it is nothing new to find in the eye of an animal lenses of different densities, but we do not recollect ever having heard of any other instance where one compound lens has been found consisting of two adherent ones of this description†. How remarkable, then, that we should discover such a phenomenon in so humble an animal as the Bee! Aye, reader; and how remarkable, too, that we should find such a contrivance adopted by man in the construction of what he at present considers the most perfect microscopic lens!

* We believe the credit of this discovery is due to Dr. J. B. Hicks.

† It is not unlikely that the eyes of other insects are similarly constructed.

With untiring patience and perseverance his mind was directed to the attainment of this end, namely to correct the aberration of light, which caused his lenses to colour and distort the objects under investigation, until he found that, by employing compound lenses of varying densities, this evil effect was counteracted; and now we see that the Creator had, probably before man was brought into existence, constructed the eye of the Bee on the same principle.

There is one thought that cannot fail to present itself to the reflecting mind in connexion with this analogy between the eye of the Bee and the achromatic lens, confirmatory of the great declaration that "God made man in His own image,"—Has not man invented, what He no doubt suggested, but not alone through the medium of the external senses? for man knew nothing of the compound lens in the Bee's eyelet when the idea occurred to him to construct an achromatic lens for his microscope, and yet it is obvious that he hit upon one of the most perfect means of attaining the desired end!

A word more regarding the corneal lenses of the Bee.

It appears to us questionable whether the normal shape of these lenses is hexagonal, or whether this form is not rather a necessity of growth; that is to say, we think they are normally round, but assume the hexagonal shape during the process of development in consequence of their agglomeration. If this surmise be correct, it applies equally to the compound

eyes of all insects, and our inference in this respect is drawn—

1. From the exceptional character of hexagonal or any other than circular lenses in the eyes of all animals, and from the fact of the simple eyes of insects themselves being *circular* (Pl. IV. fig. 4).

2. From the circumstance that, in the insect races, the conical lenses of the ocelli (Pl. IV. fig. 1, *b*) (to be described presently), which do *not* impinge one upon another, are not hexagonal, but round.

3. Because, in the posterior angle of the compound eye of the worker-bee, we often find some of the *corneal* or external lenses of a smaller size, and not adherent (Pl. IV. fig. 5), but having a little intermediate space surrounding each, and these facets are *invariably round.*

4. From the fact that in one insect at least, the Sheep tick, *Melophagus ovinus,* which ranks very low in the scale of development, we find ALL the external facets of the compound eyes non-adherent and circular*.

So much, then, for the corneal lens of the ocellus of the Bee, a compound hexahedral prism with double convex surfaces. Following the course of a ray of light after it has passed through this lens, we find that it traverses a vacant space (Pl. IV. fig. 1, *c*) before entering the conical lens (*b*), this space being surrounded by the dark pigment already referred to (*d*), and constricted or narrowed midway into the form of a round

* A careful examination of the eye in the pupa, whilst in process of development, confirms the opinion here expressed.

hole, on the same principle as the diaphragm in the eye-piece of a microscope or in the Coddington lens.

This natural diaphragm is so formed, that the amount of light which is permitted to pass, is to some extent limited, and any remaining tendency to aberration in this wonderful instrument is thereby completely corrected. The same layer of dark colouring-matter is continued downwards (Pl. IV. fig. 1, *d' d' d'* & fig. 3) between the conical lenses, so that these are effectually isolated, and the rays cannot become confused by passing from one lens to the other. The *conical* lens (*b*) is curiously shaped, but simple in its structure, not being compound, as is the corneal lens, but of the same density throughout. It is also double convex, the base as well as the apex (from which the point is removed) presenting rounded surfaces.

At the apex it comes into contact with the bulbous expansion of the optic nerve (Pl. IV. fig. 1, *e*), which receives the image of the external object, and this nerve proceeds downward in a line continuous with the axis of the ocellus, until it meets the nerves of the other eyelets (Pl. IV. fig. 3). These then unite and form a common trunk that communicates with what we may popularly call the insect's brain (strictly speaking, the "*cephalic ganglia*," Pl. VII. fig. 2, *a*).

But you may, perhaps, be puzzled to understand how so many small images, as must necessarily enter the compound eye of the Bee, can become amalgamated and combine to form a single picture of the external field; the effect will, however, be perfectly

clear to your mind, if you only consider the action of our own two eyes, which convey to our brain not *two*, but only one distinct image of the surrounding objects; and supposing that, instead of two, we had a considerable number of eyes *properly disposed*, the ultimate effect would be just the same. Now, an examination of the external lenses of the compound eye of the Bee shows that their surfaces, especially the inner ones, are not all of equal convexity, and there appears to be, as we might expect, such an arrangement and disposition of the whole mass, as to ensure the most perfect cooperation between each lens and the surrounding ones. We also find regularly scattered over the surface of the cornea—in fact, one between almost every lens and its neighbour—a great number of long hairs, and these also aid, no doubt, in the stoppage or diversion of indirect rays that might tend to confuse the common image.

In a former work* we expressed the opinion that the object of these numerous facets in the compound eyes of insects is to render the external field clearer when the insect has occasion to enter the dim hollows of flowers and other dark places in search of food, through the formation of a single picture by the union of a great number of smaller images; and this view would appear to receive striking confirmation from the organs of vision in the Bee, which spends a considerable portion of its time in the corollæ of flowers, or in the darkened hive.

* 'The Earthworm and Housefly.'

Here we find the facets to be very numerous and complex; and in the drones, which rarely quit the hive except to swarm, or accompany the queen in her wedding flight, they are much larger and more numerous than those either of the queen or worker.

It is not yet decided what the drones do in the hive; but to suppose, with some naturalists, that they have no occupation whatever, and consequently that so much additional care has been bestowed by Nature upon their organs of vision without a definite object, is quite opposed to our views regarding evidences of design. For the credit of the "male sex," we trust that they will be found to have some duty allotted to them; but of this, more hereafter.

With respect to the simple eyes (*stemmata*) of the Bee, they are, as before stated, three in number, and disposed in a triangle between the two compound eyes (Pl. III. fig. 1, *b b*). They are very simple in structure, probably even more so than has been supposed by some of our leading physiologists.

Siebold and others describe them as consisting of two lenses, an outer *meniscus* lens (convex outside and concave inwards), and an inner, almost globular one*. So far, however, as our investigations and experiments enable us to judge, there is only *one* simple lens, that one being nearly globular (Pl. IV. fig. 4, *a*); and immediately behind this lens is the expansion of the optic nerve, composed of what are termed *papillæ* —little bulbous subdivisions of the nerve, between

* The "outer lens" is a layer of integument.

PLATE IV.

Fig 1.

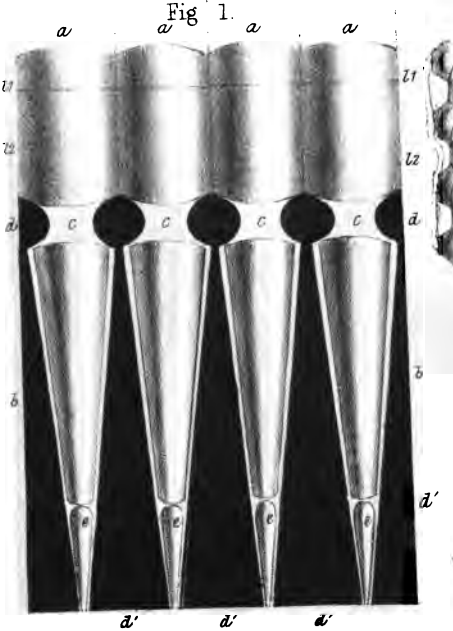




Fig. 2.

Fig. 3.



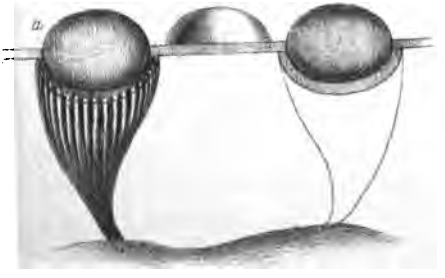


Fig. 4.

Fig. 5

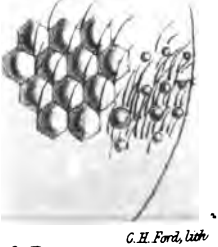
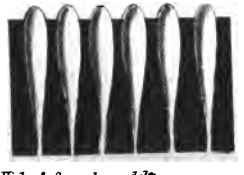


Fig. 6.



J.B Hicks & Samuelson, del?

C.H. Ford, lith

Structure of eyes, *(Compound & Simple)* of Bee.

John Van Voorst, London.

CHAPTER III.

THE ANTENNÆ OR FEELERS OF THE BEE; THEIR STRUCTURE, AND ANECDOTES CONCERNING THEIR EMPLOYMENT.—THE REMARKABLE MASTICATING APPARATUS; ITS SAW-LIKE JAWS, CUTTING BLADES, AND EXQUISITE LIGULA OR TONGUE; THEIR USES.—THE THORAX OR CHEST.—THE LEGS: WONDERFUL CONSTRUCTION OF THE BEE'S HIND-LEGS; THE POLLEN-BASKET AND PLIERS.—HOW THE BEE COLLECTS ITS PROVENDER.—WING OF A BEE AND ITS COMPONENT PARTS.—CURIOUS CONTRIVANCE FOR LOCKING THE WINGS TOGETHER.—USES OF THE WINGS.—THE STING; ITS BARBS AND POISON-BAG.—SUMMARY.

HAVING carefully examined the complicated anatomy of the eyes of the Bee, the next organs upon its head that we shall have to consider are its antennæ or feelers (Pl. V. fig. 1, *a*, & fig. 2). These appendages are thread-like or *filiform*, as they are scientifically denominated; and if you examine them with a lens, you will find that they are composed of thirteen cylindrical joints of nearly equal diameter, the second from the head being, however, much longer than the rest, and comprising above one-third of the whole antennæ (Pl. V. fig. 2, *a*). With the exception of this one, all the annulated segments of the antennæ are studded over with perforations similar to those upon the third joint of the Housefly. These perforations will be more readily detected through the employment of a low magnifying power (fig. 3), or,

still better, if one of the antennæ be bleached with chlorine, and a portion of it be then submitted to microscopic investigation. Then you will be able not only to distinguish the peculiar structure of the organs with which it is covered, and to perceive that they are closed sacculi (little sacs), but you may also trace the central nerve that runs along the whole length of the feeler, giving off innumerable branches, one of which communicates with each of the cavities on the surface (Pl. IV. fig. 3, *a*, & fig. 4). This connexion of the vesicles or sacculi with the nervous system in the manner just described, denotes clearly that they are organs of sense.

Thus much has been determined with tolerable certainty; but now comes the problem—what is the character of the sensory function performed by these antennæ? is it that of hearing, smell, or touch?

That they are organs of touch is decided beyond a doubt: but whether there is combined with this sense that of hearing or smell, or whether the vesicles are organs that convey external impressions to the nervous centres in a manner inappreciable by us, is still an open question; for however carefully they have been examined and compared with the sensory organs in other races of animals, no physiologist has yet been able to pronounce definitely as to their true function*.

* The opinions of various naturalists in this respect will be found in the 'Earthworm and Housefly,' p. 37, and note; and in various contributions by Dr. Hicks to the Transactions of the Linnean Society.

The Bees employ their antennæ for various purposes; amongst others, to ascertain the character and form of objects and substances, as a guide in the construction of their cells, and to communicate information to one another, the last-named end being accomplished by crossing their feelers with those of their congeners.

Whilst its antennæ remain unimpaired, the instincts of the Bee are wonderfully active and acute; but as soon as it is deprived of these mysterious organs, its whole nature seems to undergo a change, and its psychical or mental state may then be compared to that of an imbecile or insane person—to one, in fact, who has "lost his senses."

With the view of illustrating this observation, we shall repeat two anecdotes related by Huber, and transferred from the pages of Messrs. Kirby and Spence:—"You have seen that the organ of the language of ants is their antennæ. Huber has proved satisfactorily that these parts have the same use with the Bees. He wished to ascertain whether, when they had lost a queen (intelligence which traverses a whole hive in about an hour), they discovered the sad event by their smell, their touch, or any unknown cause. He first divided a hive by a grate, which kept the two portions about three lines apart, so that they could not come at each other, though scent would pass*. In that part in which there was

* If scent would pass and did not fail to attract the Bees, sound would pass also; according to Huber's views, therefore, it

no queen the bees were soon in great agitation, and as they did not discover her where she was confined, in a short time they began to construct royal cells, which quieted them. He next separated them by a partition through which they could pass their antennæ, but not their heads. In this case the bees all remained tranquil, neither intermitting the care of the brood nor abandoning their other employments, nor did they begin any royal cell*. The means they used to assure themselves that the queen was in their vicinity, and to communicate with her, was to pass their antennæ through the openings of the grate. An infinite number of these organs might be seen at once, as it were, inquiring in all directions, and the queen was observed answering these anxious inquiries of her subjects in the most marked manner, for she was always fastened by her feet to the grate, crossing her antennæ with those of the inquirers. Various other experiments, which are too long to relate, prove the importance of these organs as instruments of communicating with each other, as well as to direct the Bee in all its proceedings."

But the second anecdote will exhibit to us the disastrous effect produced by the loss of these organs.

"The amputation of *one* of the antennæ of a queen-bee appears not to affect her perceptibly, but cut-

would appear that the antennæ (which he shows to be the media of communication) were neither organs of scent nor of sound.

* This will be explained hereafter; it indicates that they knew the queen to be present.

ting off both these organs produces a very striking derangement of her proceedings. She seems in a species of delirium, and deprived of all her instincts; everything is done at random; yet the respect and homage of the workers towards her, though they are received by her with indifference, continue undiminished. If another in the same condition be put in the hive, the bees do not appear to discover the difference, and treat them both alike; but if a perfect one be introduced, even though fertile, they seize her, keep her in confinement, and treat her very unhandsomely. One may conjecture from this circumstance that it is by those wonderful organs, the antennæ, that the bees know their own queen."

Although we are not in a position to state decidedly what is the precise function of the antennæ, we may mention that the opinion, derived chiefly from their anatomical structure, is gaining ground, that they are organs of hearing as well as touch, and the mode of their application leads to the same belief. The question is however, as before stated, still undecided, and it presents a most interesting field for research, not only to those who employ the microscope in the investigation of the anatomy of insects, but also to naturalists who observe their habits, and in either case the careful student can hardly fail to throw additional light upon the inquiry*.

* There is no doubt whatever that the Bee possesses the senses of touch, hearing, and smell, or functions corresponding therewith; the difficulty is to assign to them a locality.

Having now examined the mysterious antennæ, and briefly referred to the present state of our knowledge regarding their functions, let us ask you once more to take up your lens and proceed with us in the investigation of the Bee's head, of which we have not by any means exhausted the scientific treasury. At the first glance, however, it is difficult to discover any other features of interest upon this part of the body; but a more careful investigation, especially in the living Bee, soon reveals an apparatus as complicated and remarkable as any that is to be found in the insect world.

The next time you observe a Bee as it enters the corolla of some fragrant flower in search of honey, take notice of the appearance presented by the pointed termination of its head (Pl. III. fig. 1, *d*), and you will see the two halves into which the extremity is divided opened from time to time, and a set of beautiful organs protruded (Pl. V. fig. 1). These constitute the *oral apparatus*, or the organs of the mouth, which lie folded up underneath the head when not in use, and to these we shall now direct our attention.

It is well known that in the most perfect form of the masticating apparatus of insects, there are to be found the following symmetrical parts:—(1.) A horizontal labrum or upper lip, and a labium or lower lip, the latter being furnished with two lateral organs known as the labial palpi or feelers, and both lips working up and down perpendicularly like our own. These portions of the apparatus, when closed, usually

cover the remaining oral organs, which consist (2) of a pair of jaws called the mandibles, and (3) of a second pair, the maxillæ, there being appended to the latter another pair of lateral feelers (the maxillary palpi): the maxillary organs work at right angles to the upper and lower lip, that is to say, *horizontally*, and operate after the manner of a pair of scissors.

Now, in the Coleoptera, or Beetle tribes, especially those that gnaw wood or other hard substances, the jaws are very powerfully developed, whilst in some other insects these organs are transformed into what is termed a "proboscis" or suction-pump, with which the creature secures the ambrosial juices of flowers. Again, in the Fly, &c. there exist, coupled with this proboscis, a pair of lancets (metamorphosed maxillæ), wherewith the insect is enabled to puncture the substances from which it extracts the juices; and this type reaches its highest development in the dreaded Gnat, where we find almost the whole apparatus to consist of a series of long pointed instruments, that inflict so painful a wound even upon man.

But far more extraordinary than all these types, and perfectly adapted in every respect to the ends required, do we find the oral apparatus of the Bee, which presents a beautiful combination of the foregoing varieties of structure.

Its mandibles form, when closed, the split, pointed termination of the head (Pl. III. fig. 1, *a*); but when they are separated, they will be found to resemble a pair of serrated or toothed pincers (Pl. V. fig. 1, *b b*).

These instruments, which are obviously intended to enable the little worker to bruise, crush, or divide hard substances, are extremely strong and solid, being composed of the same dark, horny, opake substance (chitine) as that constituting the rings of the body; whilst the remaining parts of the oral apparatus, although horny, are translucent and of a bright straw colour. The most conspicuous of these are the *maxillæ* (Pl. V. fig. 1, *c c*), two long pointed blades, whose thin edges work one against another like those of a pair of ordinary sheep-shears, which instrument they indeed resemble in shape, and along the middle of each blade there runs a longitudinal rib covered with hairs. At this part the blade suddenly becomes thin and transparent, forming the edge, whilst the back is much stronger and thicker, being supported by a series of transverse ribs (Pl. V. fig. 1, *c' c'*); these ribs, on being closely examined, are found to resemble those in the proboscis of the Fly, and their function has long been a subject of controversy: in all probability they merely form a basis of support to the organs in which they are present.

This shape or structure of the maxillæ or jaws is doubtless the most perfectly adapted to aid the insect in cutting and moulding its wax, in which operation it also employs the exquisitely-formed *ligula* or tongue (Pl. V. fig. 1, *d*).

The *ligula*, along with the two lateral feelers (labial palpi), constitute the remaining portion of the oral apparatus; and the former is of the most delicate con-

struction, being covered along its whole length with regular and symmetrical circlets or wreaths of fine hairs, and terminated by a little flat lenticular expansion, as represented in Pl. V. fig. 1, *d'*. It is the opinion of some authors, that the ligula, unlike the proboscis of the Butterfly, which operates as a tubular suction-pump, is employed by the insect to lap the honey after the manner of the tongue in the higher animals. A careful examination of the organ, however, shows that it is furnished with a long thin tube, which, commencing at the root, traverses the whole length, and terminates at the little expansion referred to. This tube (which can be detached) may perhaps be partially open on one side, or, judging by its appearance at the base of the ligula, it is probably so formed that it can be closed at the will of the insect; but there can be little doubt, from its whole appearance and its connexion with the terminal disc, that it serves to convey the nectar to the mouth. Lastly, the labial palpi (Pl. V. fig. 1, *e*) are articulated and terminated by little knobs covered with hairs, and, as already observed, when not in use, the whole of this complicated apparatus lies folded up and concealed behind the pointed termination, and beneath the under surface of the head.

With regard to the oral organs of the Bee, we have only further to observe, that although at first sight it may appear strange that so humble an insect should be thus remarkably endowed, it will no longer be a matter of surprise when we come to consider

Fig. 3.

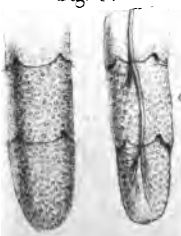


Fig. 1.

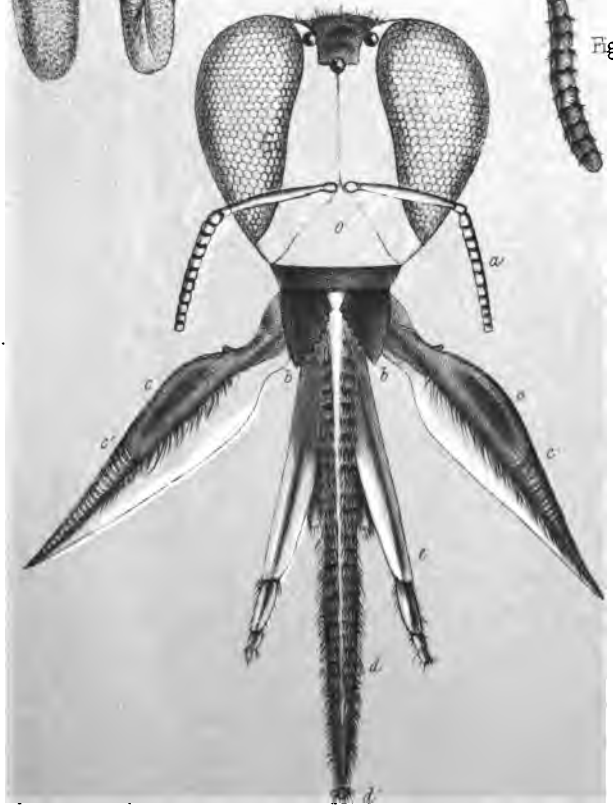


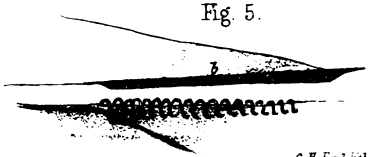


Fig. 2.

Fig. 4.



Fig. 5.



Samuelson & Hicks, del.

G.H. Ford, lith.

Anatomy of Head, & Hooklets of Wing of Bee.

John Van Voorst, London.

its various occupations. Then, indeed, you will rather be disposed to wonder how so simple an apparatus can be made subservient to such a variety of purposes, as the gathering of honey, the kneading, cutting, manipulation and adjustment of wax, the plastering of propolis, the feeding of the young, and many other employments too numerous to be recorded.

Having thus completed our survey of the organs and appendages situated upon the Bee's head, let us now proceed to the consideration of those upon the *thorax* or chest. This segment of the body (Pl. II. figs. 1, 2, *b*) is subdivided into three sections or imperfect rings, the anterior of which is called the *pro*thorax, the middle the *meso*thorax, and the posterior the *meta*thorax. As stated in a former chapter, the members of locomotion, which are all appended to the chest, consist of three pairs of legs and two pairs of wings; whereof the two anterior legs are situated upon the prothorax; the middle pair of legs, along with one pair of wings, upon the mesothorax; and the third, or posterior pairs of legs and wings, are connected with the metathorax.

The leg of the Bee, like that of all other insects, is composed of five limbs or members, some of which possess features of great interest in relation to the functions that they have to perform; for you must know that the legs of the Bee serve the insect not only as members of locomotion, but also, as you will see hereafter, in various other ways connected with its daily pursuits in and out of the hive.

The first of these five limbs, the *coxa* or hip, is short and round, being the joint that articulates with the body (Pl. VI. fig. 1, *a*); the second, the *trochanter* (*b*), another small roundish joint; then the *femur* (*c*), a thin elongated division; the tibia (*d*), a stout thick limb, which in the hind-leg becomes gradually wider as it recedes from the preceding one; and lastly, the *tarsus* or foot (*e*), which is subdivided into five smaller articulations or segments, the terminal one comprising a pair of hooked claws.

A comparison of the figures representing the three kinds of Bee (worker, drone, and queen) will serve to show you that the legs vary somewhat in their proportions; but as the posterior or hinder pair, especially in the worker-bee, possess all the interesting features common to the remaining pairs, and some characteristics peculiar to themselves, we shall only bring our lens and microscope to bear upon the remarkably constituted hind-legs.

The most superficial inspection of one of these members (Pl. VI. fig. 1) cannot fail to suggest the idea that it must perform some other function besides that of locomotion. First of all, its limbs or joints are of a very curious shape, and unlike those of other insects; for the fourth limb or tibia (*d*) becomes very broad as it approaches the fifth, that is, the tarsus, the first joint of which is also *very* largely developed (*e*), being of an oblong shape, and covered over its whole surface with regular rows of long stiff hairs. And then, if you examine the junction of

these two divisions of the leg (Pl. VI. fig. 1,*j*, and fig. 2), another peculiarity presents itself: namely, a cavity formed by the uppermost edge of the first joint of the tarsus and the lower edge of the tibia, which cavity (Pl. VI. fig. 2) resembles an open vice, and may be closed from the joint at the will of the insect. But this is not all: on the upper side of this receptacle (for this is the well-known pocket or pollen-basket of the Bee), you will find a row of long lancet- or sword-shaped hairs (Pl. VI. fig. 2, *a'*), regarding the use of which we need not long remain in doubt. Here it is that the industrious worker commences the storing up of her "bee-bread," which consists of the pollen of flowers moistened with honey; the first deposition being no doubt pressed together and consolidated by the prongs and the vice referred to, and particle after particle added, and in like manner rendered consistent by the rows of long hairs distributed over the first joint of the tarsus, until the whole pollen-mass assumes the form of those curious pellets that you may see encumbering the little caterer as she returns home from her aërial wanderings. The sides of the tibia, as well as those of the first joint of the tarsus, are slightly hollowed, whereby the deposition and retention of the bee-bread are greatly facilitated.

And now let us travel on to the *last* joint of the tarsus (Pl. VI. fig. 1, *e'*, & fig. 3), furnished with its remarkable terminal claws, and we shall find that it is hardly surpassed in interest by the wonderful feet

of the Housefly, whereby that insect is enabled to progress so readily upon glazed or inverted surfaces*.

In the Bee the claws are *forked* (Pl. VI. fig. 3), and not simple, as in the Fly; and whilst the latter has *two* beautiful pads, the insect under consideration is provided with only *one* central, hollow, cup-shaped organ (Pl. VI. fig. 3, *a*), studded all over with innumerable hairlets. The reason for this difference in the construction of the feet of the two insects is obvious enough. The central cup-shaped organ of the Bee no doubt operates as do the pads in the Fly, giving the insect a hold upon smooth surfaces: but, as you will probably yourself have noticed, the Bee does not move over such surfaces with the same facility as the Fly, nor has it occasion so to do; it has therefore only one pad, more simple than those of the Fly. But, on the other hand, having frequent occasion to use its claws in its domestic operations, such as the adjustment of wax, pollen, &c., these instruments are, as just observed, of a more complicated structure than those of the Housefly.

Thus you see that even on the hind-leg of a Bee, there are to be found various appliances well adapted to the uses for which they are intended, but not at all requisite for the mere act of locomotion; and if we now proceed to investigate the wings of the insect, we shall in like manner be surprised at the discovery of exquisite contrivances that are applicable

* 'Earthworm and Housefly,' p. 51.

to other uses than that for which organs of flight are usually destined. The wings are, as before stated, four in number, the anterior pair being the largest (Pl. II. figs. 1, 4). They are composed of a double membrane which is covered all over with fine hairs, and stretched out upon what are termed "nervures," or ribs, that ramify between the double fold. (Pl. VI. fig. 4.)

Accompanying the nervures are also to be found a set of vessels for the circulation of air (tracheæ), and another set for the passage of blood; and although the nervures are not so numerous in this as in some other insects, they are of a firm consistent nature, giving to the wings that tough membranous texture which characterizes the order (Hymenoptera).

But you may be disposed to ask *why* the wings of a Bee should require to be tougher and more resisting than those of other insects. This would be a very natural inquiry, and one that we shall seek to answer satisfactorily; but, before doing so, let us for a moment direct your attention to another feature in connexion with these organs. Supposing it to be necessary that they *should* offer great resistance to the atmosphere and present the broadest possible unbroken surface, this object would of course be greatly facilitated if the two pairs of wings could be locked together in such a manner that it would be impossible for a current of air to pass between them. Well, then, without rendering them permanently adherent, which would make it inconvenient for the insect to

fold its wings, Nature has, by a beautiful but simple contrivance, attained this end: for, if you take your lens and examine the anterior or front edge of the *hinder* wing (Pl. VI. fig. 4, *h* and Pl. V. fig. 5), you will be surprised to find a row of exquisitely formed hooks; whilst, on the opposite edge of the *anterior* wing with which this row of hooks comes into immediate contact, you will be able to detect a species of rib or bar (Pl. V. fig. 6, *b*), to which the hooks may be made to adhere firmly, and both wings thus attached to one another when *requisite*, presenting the desired unbroken surface to the atmosphere.

And now, reader, the *reason* why these wings are of a tough resisting nature, and so wonderfully organized, is because they are not only employed in flight, but also (as we shall see hereafter) in the ventilation of the hive: in the latter capacity the insects cause them to vibrate very rapidly, so as to create a current; in fact, they operate precisely on the principle of the fan. It is hardly necessary, we presume, to point out to you how inefficient such an instrument would be if it had a slit down the middle; and you will now perceive why it is necessary that the fore and hind wings of the Bee should be capable of being locked together, so as to present one continuous unbroken surface.

At the roots of the wings, upon what is termed the sub-costal nerve, there are to be found a number of pear-shaped vesicles, of a somewhat similar character to those described upon the antennæ; here, however,

they are open within and elevated above the surface, and not, as in the antennæ, depressed or indented. In like manner they can only be carefully investigated when the colouring matter has been removed through the agency of chlorine, and then a high microscopic power reveals similar bundles of fine nerves leading to the vesicles, and connected by a trunk to the central ganglion or nervous mass. These nerves prove the vesicles, as in the former case, to be organs of sense, and Dr. Hicks has attributed to them the function of smell. This inquiry must, however, still be considered an open one; and here again (not only in the Bee, but in all other insects) an excellent field is presented for the investigations of young naturalists. Beyond these vesicles and the hooks, the wings do not possess any other feature of interest whereon we feel tempted to dwell (the tracheæ or respiratory vessels will be described hereafter); and as the thorax, which has furnished us with its fair share of instruction, has no other appendages than those already described, we shall now proceed to examine the only organ that is visible upon the third or abdominal segment of the body, that is, the sting, and therewith conclude our survey of the external organs and members of the Hive-Bee.

If you were ever stung by a Bee, and, after extracting the sting, had the curiosity to examine the weapon that caused you so much pain, you would probably have been puzzled to conjecture how an object apparently so insignificant could produce such a serious

effect. But the fact is, that the sting of a Bee is not simply, as it might appear at first sight, a little splinter, resembling those fragments of thorn that we occasionally find to have penetrated our skin during a country ramble; but it is a highly organized apparatus, upon which the penetrating power of the lens must be brought to bear in order to reveal its formidable character.

The little instrument known as the sting, is found, when magnified, to be the sheath in which the true sting lies concealed, although the whole enters the wound when an attack is made. The piercing apparatus itself is, however, double (Pl. VI. fig. 5, *b b*), being composed of two long darts, which, in the illustration, are removed from the sheath and separated in order to exhibit their shape, but in their natural position are placed side by side, so as to form a lance; and being furnished with suitable muscles, they are forcibly protruded from the sheath (Pl. VI. fig. 5, *a*) when required for the purposes of attack or defence. But our investigation must not stop here; for if we employ a tolerably high microscopic power to examine the points of these darts, we shall find them to be barbed (Pl. VI. fig. 6), each piercer being furnished on one side with eight teeth; and as they are so placed when in use that the smooth edges are in juxtaposition, you will perceive that they then constitute a single formidable barbed spear, similar to one of those primitive weapons of warfare employed by the savage inhabitants of various countries, that you will no doubt often have

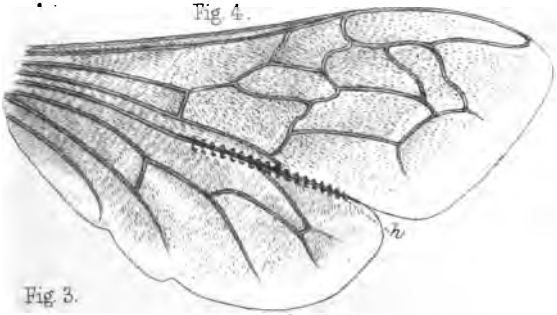
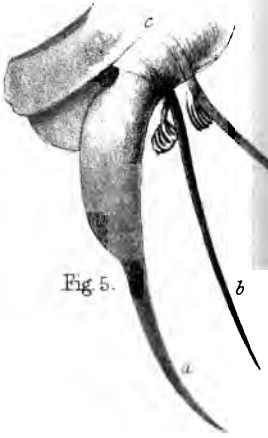


Fig. 3.









James Samuelson, del.

Anatomy of hind leg, Wing & Sting of Worker Bee.

John Van Voorst, London

met with in museums or collections of ethnological curiosities.

You will now perceive what a formidable weapon the sting must be when directed by the Bee against an insect of its own size; and, after examining its barbed points, you will easily understand, too, how it happens, that, when the little belligerent manages to penetrate your own skin, it should be compelled to leave its sting behind.

But there is another and still more dangerous feature connected with the instrument than even these barbs, namely that it is poisoned; for, situated at the root of the sting, there is a little sac, containing an acrid fluid, supposed by some naturalists to be pure formic acid, and secreted by a pair of tubes appended to the receptacle*. At the moment when the sting enters the object attacked, the same muscles by which it is worked express a drop of the fluid from the sac, and this, passing through the hollow sheath into the wound, causes the instantaneous death of the animal attacked, should it be another insect; whilst even man suffers considerable pain from the inflammation resulting from the poison. The best mode of extracting the sting, as well as the drop of fluid, is by pressing the open end of the barrel of a key upon the puncture; this forces out both sting and poison, and affords instantaneous relief.

In the queen, the sting, which is curved, is also a modified ovipositor (Pl. II. fig. 20), serving to aid her

* Want of space has prevented us from presenting an illus-

in the deposition of eggs, as well as to attack her enemies; and with what terrible effect she employs the instrument for the latter purpose, we shall see hereafter.

And now, reader, having concluded our review of these various organs and members, we would ask you to reflect for an instant upon what we have together examined.

Can you imagine that all these wonderful contrivances, the superficial account of which has occupied two chapters;—that the mysterious antennæ, studded over with innumerable organs of sense; the eyes, composed of 4000 lesser organs of vision, as perfect in their construction as our most highly prized philosophical instruments; the oral apparatus, consisting of shears, and saws, and cutting blades; the curious legs, provided with baskets for the conveyance of food to the hive, and pliers to aid in the construction of that dwelling; the wings, formed not only as members of locomotion, but also to fulfil the important process of ventilation; and, lastly, the sting, with its poisoned barbed lance;—can you conceive, we say, that all these remarkable mechanisms exist upon the common Honey-Bee, which you have many a time brushed from your window-pane when it dared to venture inside your dwelling?

So, however, it is; and you have perhaps thought no more of these various wonders in the little

tration of the poison-sac, which is situated within the abdomen, about *c*, fig. 5, Pl. VI. Pl. VIII. fig. 2, *p* represents one of the secreting tubes.

honey-maker than of the insect itself when you sat down at your breakfast-table to enjoy the sweet fruits of its labours, in which these very instruments were employed!

But rest assured that the consideration of the various appliances wherewith the Bee is furnished (the greater portion of which can be easily distinguished even with a pocket lens) would in no way detract from the enjoyment of the sweets that they help to produce; and let us therefore recommend them, when the opportunity next presents itself, to your careful study and investigation.

CHAPTER IV.

INTERNAL ANATOMY OF THE BEE.—ORGANS OF DIGESTION.—GASTRIC TEETH.—RESPIRATORY SYSTEM.—SPIRACLES OR BREATHING-HOLES, AND TRACHEÆ OR AIR-TUBES.—THEIR BEAUTIFUL CONSTRUCTION AND DISTRIBUTION THROUGH THE BODY.—NERVOUS AND CIRCULATING SYSTEMS: THEIR RELATIVE POSITION IN THE BEE.—DORSAL VESSEL AND PHENOMENA OF CIRCULATION.—NERVOUS SYSTEM.—ORGANS OF REPRODUCTION IN THE QUEEN-BEE.—OVARIES, ETC.—METHOD WHEREBY THE EGGS ARE FERTILIZED, AND REMARKABLE POWER OF REPRODUCTION IN THE VIRGIN QUEEN.—STING.—UNITY OF DESIGN IN THE BEE'S STRUCTURE.

If we have found in the external structure of the Bee interesting subjects of observation and inquiry, so shall we also be able to discover in its internal physiology features that are equally deserving of our careful attention.

Here, however, the magnifying lens alone will not suffice, and we must first borrow the scalpel of the anatomist, and penetrating the solid integument of *chitine* that forms the external supporting frame of the insect, to which the various muscles are attached, we must lay open the several divisions of its body, and then examine them through the scrutinizing medium of the lens.

In so doing, we shall have to proceed upon a different plan from that employed in making ourselves acquainted with the character of the external organs and members; for whilst these were *local*, each having its appointed place upon some special portion of the body, the *nervous*, *respiratory*, *circulating*, and *digestive* systems, will all be found to occupy a more or less prominent position in each of the three sections; the *reproductive* organs alone being confined to the abdominal segments.

Whilst examining the oral apparatus, or mouth of the Bee, we had occasion to consider and describe a variety of instruments to whose action the food is subjected before its admission into the body; and we shall now follow it in its course through the *digestive system*, dwelling for a while upon each organ through which it is obliged to pass. The nutriment of the Bee is of a varied kind, being sometimes solid, as the Bee-bread or pollen, and at others consisting of liquid honey. In either case, it must first enter the *œsophagus* or *gullet* (Pl. VII. fig. 1, *a*), a portion of the digestive system analogous to the throat in the higher animals: this canal or tube traverses the whole length of the thorax, and leads into the first stomach (*b*), the *crop*, *paunch*, or *honey-bag*, as it is variously denominated.

Should the food consist of the nectar of flowers, it is probable that, after being retained in the honey-bag until the Bee has found its way back to the hive, it will be regurgitated into the cells of the

honeycomb, and there add food to the general store; but if solid, and destined for the nourishment of the insect itself, it passes down into the *true stomach* (*c*), where it comes under the influence of what are called the *gastric teeth*, and undergoes a second mastication while being digested.

These gastric teeth, which are formed of silica, and are consequently very hard, are present not only in the stomach of the Bee, but in many other insects, even in those that subsist on liquid nutriment; in the Blow-fly and Butterfly, for instance, which suck the juices of plants, &c., their structure is very complicated, for, although of delicate proportions, they have a curiously branched form.

This may appear a somewhat superfluous endowment on the part of Nature, and you will perhaps be inclined to ask, what can be the use of these diminutive teeth where the food is of such a character as to need no mastication? A little reflection will, however, show that it is in those very insects which subsist on liquid food that they are the most wanted, for, since they possess (as in the instances just quoted) no masticating organs at the mouth, there is all the more necessity for some internal contrivance to reduce the solid alimentary particles that may enter at the throat, either accidentally, or in consequence of the food being of a rather more consistent nature than usual; and for every such contingency Nature makes due provision. Now, in the Bee the gastric apparatus is very simple, *probably* for the opposite reason

to that assigned for the complicated teeth of the Butterfly, &c., namely, because it possesses powerful masticating organs at the mouth, and here we find it to consist of a number of straight, sharp, siliceous teeth, of very insignificant proportions (Pl. III. fig. 4), which are discernible only under a high microscopic power.

From the stomach the food passess into a short intestine, narrow at first, and widening as it proceeds downwards. About the middle, this intestine receives a number of tubular glands, known as the "*biliary tubes*" (Pl. VII. fig. 1, *d*), which correspond in some degree to the liver in vertebrate animals, and pour out their fluid upon the food in its passage through the intestine. Further on, this canal becomes much wider, and is then known as the "*colon*" (Pl. VII. fig. 1, *e*), which is the termination, not only of the intestine, but of the whole digestive system. The remaining parts of the apparatus are not of sufficient interest to the general reader to induce us to dwell upon them, and we shall therefore pass on to that remarkable and deeply interesting portion of the Bee's anatomy, the *respiratory system*.

The Bee, in common with most other insects, does not breathe as we do through apertures in the head, but the air is admitted by special organs situated upon the surface of the body. These are called *spiracles* or *stigmata*, and consist of little holes pierced in the external integument, two pairs being

situated on the thorax, and a pair upon each ring of the abdomen.

In the common Housefly, these spiracles are very beautifully formed, the entrance being partially closed by a great number of ramifications of the external covering of the body, proceeding from the circumference of the spiracle, and forming a delicate network, the object of which is to prevent particles of dust from entering along with the atmosphere. In the Bee, however, the contrivance is of a different kind, consisting of two elongated apertures, one behind the other (Pl. VII. fig. 3), and the outer one only provided with a number of short hairs for the purpose of precluding foreign substances, instead of the beautiful ramifications that are present in the Housefly.

Through these spiracles or breathing-holes, then, the air is admitted into special organs which enable it to circulate through the body (Pl. VII. fig. 2, *a a' b*, &c.*), and consisting of a number of sacs or bladders that communicate with one another, and with the external atmosphere, by means of wonderfully constructed tubes, called *tracheæ*.

The distribution of these sacs and tubes is deserving of especial attention, and we must ask you to accompany us in an examination of the plate representing this portion of the insect's anatomy (Pl. VII. fig. 2, *a a' a'*, and *b b b*, &c., the part drawn in tint).

* The respiratory system is represented by the large sac and connecting tubes at the *left* side of the figure.

In explanation, however, it is necessary to remark that, although only one set of organs is here delineated, they are *bilateral*, that is to say, distributed in pairs symmetrically on either side of the body. The largest pair of sacs is found in the abdomen (Pl. VII. fig. 2, *a*); from these proceed two main trunks, the one (*b*) upwards into the thorax, and the other (*c*) down to the termination of the abdomen. The latter gives out large branches ending in sacculi or little sacs (*d*), whilst the tubes that pass upwards (*b*) traverse the thorax in a straight line without any ramification whatever, and only in the head do we find a second pair of sacs (*a'*) of considerable dimensions. You will see, therefore, that the greater number of the respiratory vessels are to be found in the head and abdomen, especially in the latter, and the reason for this arrangement is simple and instructive. The abdomen contains all the viscera, and is by far the heaviest part of the body; it has therefore the greatest need of the inflated air-vessels to give it support, and to some extent this applies also to the head with its large solid eyes, whilst the thorax is effectually buoyed up in the atmosphere by the powerful double wings: thus, you see, the equilibrium is maintained throughout every part of the body.

Not only has Nature been thus far consistent in the disposition of the respiratory vessels, but we find that in the queen-bee, which quits the hive and takes her flight in the air only twice or thrice during her

lifetime, and whose abdomen is necessarily filled with an immense number of eggs (Pl. VIII. fig. 1), the large respiratory sacs are quite wanting, and the only air-vessels are the larger and smaller tracheæ.

But by far the most remarkable feature in connexion with this portion of the Bee's anatomy is the structure of the tracheal tubes themselves. On examining one of these under the microscope (Pl. VII. fig. 4), you will find it to consist of a double membrane supported between the two folds by a coil of hair-like fibre, just as the coil of wire gives strength to the elastic gas-tubing employed to feed a table-lamp from an ordinary chandelier. The object of this arrangement is similar in both cases: the tracheæ are rendered very elastic, and any hindrance to the passage of air by their collapse is only momentary, as the supporting coil reopens the tube as soon as the external pressure is removed. A close investigation of this mechanism shows that the fibrous coil becomes more and more delicate as the tracheæ diminish in size, and that it is not continuous, but here and there a new coil commences between the folds of the preceding one.

Dismissing now this interesting portion of the Bee's anatomy, we shall direct our attention to the *nervous* and *circulating systems*, and we must commence by remarking that in the Bee, as in all other articulate animals, the relative position of these two systems is precisely the reverse of what it is in the higher animals. In the latter (taking ourselves as an example),

the spinal chord, with its nervous ganglionic centres, will be found to traverse the dorsal region of the body: they run, in fact, along the *back*, whilst the heart is situated in *front*; but in the Bee the central nervous chord passes along the *ventral* portion, whilst the tubular heart occupies a place immediately within the integument of the *dorsal* surface. The *circulating* apparatus consists chiefly, so far as anatomists have hitherto been able to trace it, of what is called the dorsal vessel (in consequence of its running along the *back* of the body). This dorsal vessel assumes the form of a tube, attached to the outer integument by bands or ligaments, and that portion of it which is situated in the abdomen is divided into eight chambers, communicating with one another by means of valves so constructed as to admit of the blood passing in one direction only, that is to say, towards the head. After it has traversed the abdominal chambers, which may be compared to the chambers of our heart, the sanguineous fluid continues its course through the thorax, where the dorsal vessel forms a simple contractile tube (the aorta) without any divisions, and thence it is forced into the head and other parts of the body.

The circulation of the Bee cannot, however, be completely traced, nor is it, so far as we are able to judge, of a perfect character; for, although it has been stated by some anatomists that a portion of the blood is conducted back from the head to the posterior part of the body by means of a smaller tube situated

on the ventral side, opposite the dorsal vessel, this is by no means established; and, on the other hand, it is certain that a considerable quantity of the sanguineous fluid finds its way into the cavities of the body (*lacunæ*), and there bathes the intestines.

This statement may perhaps cause you some surprise, for you know, no doubt, that in the higher animals an escape of blood internally, from the regular channels in which it is confined, would lead to serious, if not fatal results; and, moreover, the inquiries are at once suggested, "What becomes of the blood after it has entered the cavities of the body? and how is it that the supply is not exhausted?"

An examination of the "dorsal vessel" shows that it is not only furnished with valves that unite its chambers, but also with another set, which are placed at the side of the tube, and communicate with the cavities of the body in such a manner as to admit of the *ingress*, but not the *egress* of fluid. The blood then, after having bathed the vital organs of the body, accumulates around the dorsal vessel, into which it is admitted by this second set of valves, and again propelled forwards into the thorax. Moreover, this wonderful force-pump (the dorsal vessel), with its chambers and valves, gives out several fine branching arteries, some of which are also said to terminate in the cavities of the body*.

* The circulation of the blood in insects may be observed in some of the smaller *Diptera*, such as gnats, &c., where the external envelope is semitransparent, more easily than in the Bee.

The *nervous system* of the Bee presents the usual articulate type. It consists of a pair of straight parallel chords of nerve-substance that lie side by side, and run along the whole ventral side of the body, beginning in the head and ending near the termination of the abdomen. Upon these chords are distributed several ganglia or nervous centres (resembling pearls strung upon a couple of threads), from which branches proceed to the various organs and members of the body.

First, there is the brain (Pl. VII. fig. 2, *a*), or, as it is technically called, the *cephalic*, or *supræsophageal* ganglion. This is, strictly speaking, two ganglia fused into one, as the illustration will show, and situated (as the names denote) in the head and above the throat; each half gives out a large lateral nerve, the optic nerve (*nervus opticus*, Pl. VII. fig. 2, *o*), which divides into a bundle of finer nerves, whereof one proceeds to each ocellus or subdivision of the compound eye*.

From this ganglion also nerves depart to the simple eyes and feelers (fig. 2, *n a*). Proceeding backwards, we find another ganglion of considerable size situated below the throat, and connected with the brain by the double chord or commissure referred to: this ganglion (the *sub-* or *infra-œsophageal*, fig. 2, *b*) supplies the organs of the mouth and the first pair of feet (2, 2) with nerves. Continuing our course backwards along the central chords, we arrive at the large

* See page 26.

thoracic ganglion (fig. 2, *c*), composed of *grey* nervous matter. In the larval stage of the insect this is not one, but three ganglia, which during the metamorphosis become fused into one large ganglion*, the most considerable, in fact, in the whole body, and from it there proceed nerves to the various members of locomotion (3, 4, 5, 6, 7). Compared with the thoracic ganglion, the remaining five, all situated in the abdomen (*d*, *e*, *f*, *g*, *h*), are of very small proportions, and each gives out a pair of fine lateral nerves to the organs enclosed in the respective rings, whilst from the *last* ganglion, which is larger than the rest, there proceed a number of nerves to the reproductive organs.

And now, after this somewhat monotonous account of nerves and ganglia, we arrive at what must indeed be regarded as by far the most interesting portion of the Bee's anatomy, when considered in relation to the history of the insect; we mean the *organs of reproduction*; for their investigation has not only explained much that was before mysterious in its life-history, but has revealed some of the most remarkable phenomena in animated nature.

It has been already stated that a hive consists of three kinds of Bees: the drones or males; the workers or females with reproductive organs but partially developed, and consequently of no use in the multiplication of the species; and the queen or perfect female, the mother of the hive, in whom the reproductive system is complete. We shall now ask you to accom-

* See account of the metamorphosis, Chapter VI.

Fig. 1.

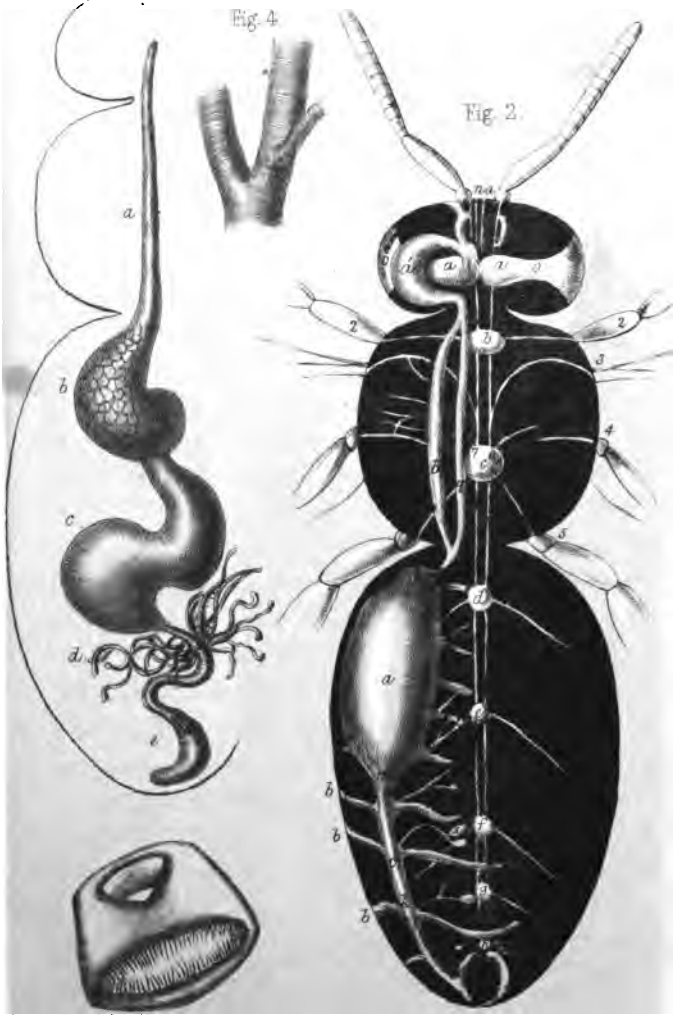


Fig. 3.

J. D. Hicks, & Samuelson, del.

G. H. Ford, lith.

Digestive, Respiratory, & Nervous System of Bee.

John Van Voorst, London

pany us in a brief survey of the organs of the Queen Bee, by means of which the hive is so rapidly and effectively stocked.

In describing the respiratory system of the Bee, you will recollect it was mentioned that the two large abdominal sacs which are always present in the worker are absent in the queen; and if you were carefully to dissect the body of the latter, you would find their place occupied by two objects resembling miniature bunches of grapes, that monopolize the greater portion of the abdominal segment; these are the two ovaries (Pl. VIII. figs. 1, 2, 3), or the receptacles wherein the eggs are developed.

They are bilateral, and composed of an assemblage of tubes collected in a bundle, and all closed at one extremity (Pl. VIII. figs. 1, 2, 3, *a*). At the other end (*b*)* they open out into what may be popularly called a common trunk (scientifically the *"proper oviduct,"* *c*, *c*), being very small at the extreme end, and gradually widening as they approach the aperture. At the narrow ends of these tubes (*a*) the *"germinal vesicles"* are formed, that constitute the reproductive element in the eggs; and as these vesicles pass downwards, or more correctly speaking backwards, to the proper oviduct, they are increased in size by the addition of the "vitelline matter," or, as it is commonly called, the yelk.

* See especially fig. 3, *b*. Fig. 1 represents the ovaries *in situ*; fig. 2, their general shape; fig. 3, the portion connected with the oviduct.

When fully formed, the ova, which appear to be arrested at a certain point near the entrance to the "proper oviducts" (fig. 3, *d*), so that the subdivision into tubes is here distinctly visible, enter these two ducts and pass on to the "*common oviduct*" (fig. 2, *e*), a large central tube formed by the union of the two "proper oviducts," and thence they are extruded into the cells prepared for their reception by the Worker Bee.

But a curious feature in connexion with this portion of the Bee's anatomy is the means provided for the fertilization of the ova; these, during their passage through the "common oviduct," come into contact with the male elements, which are deposited by the drone, and stored up in the "spermatheca" (Pl. VIII. fig. 2, *s*), a reservoir provided for the purpose, and connected by a short tube with the oviduct*. By this operation the eggs become fructified, and, in consequence of this peculiar arrangement, *a single impregnation by the male is sufficient to fertilize the queen-bee during her whole life.*

Unless you were previously acquainted with the circumstance, this statement might appear very remarkable; but, strange though it be, it is but of slight interest compared with another fact recently revealed with the aid of the microscope, and that is, that the union of the sexes is not at all an indispen-

* By the side of the "spermatheca" (the little globular vessel) will be seen two secreting tubes (*l*, *l*), whose office is not known, but which probably secrete a moistening fluid.

sable condition in the laying of fruitful eggs, but *that the queen-bee is capable of producing and depositing fertile eggs in her virgin state, from which males alone proceed*; in fact, it is now tolerably well established that the eggs wherefrom drones are hatched are in no case fertilized by the male element. To this portion of the subject we shall have to refer when we come to treat of the life-history and habits of the insect, and shall now conclude our brief survey of these interesting organs by stating that those of the male somewhat resemble the female organs in appearance, but possess no feature of sufficient interest to render them worthy of special consideration in a popular work *.

Although our review of the internal anatomy of the Bee has been so brief and imperfect (for there are many other interesting features in this portion of its frame well worthy of observation), yet, when considered in conjunction with those remarkable external organs and members described in the preceding chapter, they must have led you to expect something more than ordinary in the actions of the insect thus physically endowed; and perhaps even our physiological investigations will have called to mind many strange

* The sting, which has been described in a former chapter, may be once more referred to here, for it serves the double purpose of a weapon of attack and an ovipositor. One of the tubes that secrete the poison will be seen at *p*, fig. 2, and below *e* are situate the gland in which the poison is stored, the channel through which it enters the sting, and that weapon, with the muscles by which it is drawn into the body.

tales that you have read, or heard popularly related, in connexion with its habits and life-history. To these, then, we shall next direct your attention, and the consideration of this portion of the subject will serve to show that all the members and organs hitherto described are perfectly adapted to the performance of the functions assigned to them. Then indeed, when we come to consider the varied impulses and instincts which are the hidden springs that set in motion the visible external organs, subjects of new and surpassing interest will present themselves, and it will be a matter of wonder and astonishment how such a variety of actions and motions can be concentrated in the insignificant little Bee. Then will the contemplation of that unity which characterizes the whole insect mechanism, with its secret springs and impulses, call forth our warmest admiration, and cause us to feel

"How most exact is Nature's frame!
How wise the Eternal mind!
His counsels never change the scheme
Which His first thoughts design'd."

CHAPTER V.

THE MAN AND THE BEE.—THE BEE AND THE POETS.—CONSTITUTION OF A HIVE.—THE QUEEN AND HER DUTIES.—THE DRONES, ARE THEY MEN ABOUT TOWN? THEIR FATE.—THE WORKERS.—WAX, ITS COMPOSITION AND USES.—HONEY, ITS CONSTITUENTS; ADULTERATION, DETECTION BY THE MICROSCOPE.—KINDS OF HONEY, BEVERAGES MADE FROM IT.—ANECDOTES CONCERNING POISONED HONEY.—BEE-BREAD, ITS APPEARANCE UNDER THE MICROSCOPE, ETC.—PROPOLIS, HOW COLLECTED AND EMPLOYED; KIRBY AND SPENCE'S (HUBER'S) ACCOUNT OF ITS APPLICATION.—HOW THE BEES ENTOMBED A DEAD MOUSE AND A LIVING SNAIL WITH PROPOLIS.—NATURE AND OCCUPATIONS OF THE WORKER BEE.—WAX-MAKERS AND BEE-NURSES.—CONSTRUCTION OF CELLS.—MIRACULOUS POWERS ATTRIBUTED TO THE BEE IN THIS RESPECT.—VARIOUS THEORIES CONCERNING HEXAGONAL FORM OF CELLS: COMPARISON OF THESE THEORIES, AND DEDUCTIONS.—THE HONEYCOMB.—WORKER-, DRONE-, AND QUEEN-CELLS, AND THEIR USES.—THE LITTLE HONEY-GATHERER, HOW SHE FERTILIZES PLANTS.—HAS THE CREATOR FORMED ANY ANIMAL IN VAIN?—LIFE AT THE HIVE-GATES.—ARRIVAL AND DEPARTURE OF EXCURSIONISTS AND TRADERS.—A PEEP INSIDE.—LIVING VENTILATORS.—THE BEE AND THE MAN AGAIN.—INTERNAL ECONOMY OF THE HIVE.—APIARIAN BOARD OF HEALTH, AND BURIAL BOARD.—THE ART OF FORTIFICATION AMONGST THE BEES.

How remarkable is the analogy that exists between the natural history of the human race, as known to

us, and that of a hive of bees with its attendant swarms!

The former, we are told, took its rise in a single pair—the lord of the creation and his mate. Then followed *workers*, tillers of the soil, who sowed and reaped, constructed dwellings, and collected provision for themselves and their offspring; also warriors, who attacked and defended the city with its inhabitants; and then, in the earliest era no doubt, there arose the "privileged classes" (equivocal privileges were theirs), who lived by the labour of others, and spent their time in idleness. Next we hear of wanderings and migrations of new colonies, offshoots from the parent stock; of new cities founded by their labours and defended by their arms. So it has been from time immemorial, and so it will probably continue until the earth is fully peopled.

Now turn we to the Bees.

Their Eve may at least spring into existence (as we shall see hereafter), bearing within her the offspring, still unborn, that is to produce her whole colony. First, there appear the workers, who, like the human workers, *sow** and reap, and gather honey; the *citizens* who erect their habitations, elaborating even the necessary materials from their own bodies: next follow watchmen, warriors, and lazy drones, the privileged classes; and lastly, we have the colony, the swarm of emigrants led once more

* That they literally sow seeds we shall find to be the case when we consider the habits of the worker.

by a second Eve*, and wandering forth in search of a resting-place and new pasture grounds. And so the little *bee*-world revolves, and will continue to revolve as long as bees exist.

Never has there been a creature, unless it be perhaps the sweet-toned nightingale, that has lent inspiration to the poet's muse more frequently than the little Honey Bee; and wherefore has she received such tributes of praise? Let us answer in the words of one of her admirers:—

"Not a flower can be found in the fields,
Or a spot that we till for our pleasure,
From the largest to least, but it yields
The bee, never wearied, a treasure.

"Scarce any she quits unexplored,
With a diligence truly exact;
Yet, steal what she may for her hoard,
Leaves evidence none of the fact.

"Her lucrative task she pursues,
And pilfers with so much address,
That none of their odour they lose,
Nor charm by their beauty the less.

"Not thus inoffensively preys
The cankerworm, indwelling foe!
His voracity not thus allays
The sparrow, the finch, or the crow.

"The worm, more expensively fed,
The pride of the garden devours;
And birds pick the seed from the bed,
Still less to be spared than the flowers.

* Strictly speaking, we believe the *drones* lead the swarm; at least, so it has lately been stated.

"But she, with such delicate skill,
Her pillage so fits for our use,
That the chemist in vain with his still
Would labour the like to produce.

"Then grudge not her temperate meals,
Nor a benefit blame as a theft,
Since, stole she not all that she steals,
Neither honey nor wax would be left."

COWPER.

Poets are often apt to exaggerate, but in the case of the Bee we cannot lay this fault to their charge. There can be no doubt that this insect is in every respect one of the most interesting of all living creatures; and as the little denizen of the hive is the companion of man, and renders him essential service, it is but natural that he should receive a large share of his attention. This, too, must be *our* excuse for reproducing and endeavouring to give fresh interest to the story that has already been narrated by so many able writers, and we shall now proceed to take a peep into the bee-world, and try to penetrate some of the mysteries of the hive.

A complete community of Bees comprises—1°, one *queen*, the mother of the hive, a perfectly developed female; 2°, from 600 to 800 *drones* or males; and 3°, from 15,000 to 30,000 *workers*, to whom, although they are known occasionally to lay fruitful worker-eggs, we may give the appellation of neuters. The office of the queen-bee is to lay all the eggs that are hatched in the hive. She is moreover the constitutional head of the colony, for, although she does

nothing (so far as we know) but add to its numbers, yet, should she be accidentally or designedly removed, anarchy at once reigns in the hive; and if at such a juncture there be not one of the royal family on the way from larvahood, the constitutional Bees at once proceed by a wonderful instinct, and a remarkable artificial contrivance, to manufacture a fresh head for the state.

Of the drones little is known, for they rarely leave the hive excepting to accompany the queen on her wedding tour, and the sole object for which such numbers are produced would appear to be, in order that there may be sufficient to ensure for the queen a suitable consort.

As, however, there has been so little opportunity of investigating their habits, we must not be so uncharitable as to suppose that their life is one of complete apathy, or that these beaux amuse themselves by parading the Broadways of the hive, and flirting with the worker-ladies. It is probable that both male and female leave such frivolous pursuits to *superior beings*, who can afford thus to waste their time, for we know that the workers at least are incessantly employed in their industrial pursuits, and very likely the drones, too, have some post allotted to them. Whatever may be their duties, the services of the latter are lightly appreciated by the rest of the community; for, although they are allowed to remain unmolested in the hive during the summer months whilst food is plentiful, and a certain number ac-

company each new swarm, yet when winter approaches and there begins to be a fear of famine in Bee-land, then the ruthless workers drive the lazy drones out into the cold, and should they attempt to return, they are mercilessly slaughtered. This is an easy task, for the drones are not provided with stings, as are the queen and workers; and they consequently fall an easy prey to their amazonian congeners.

But now we come to the most active members of the community, the workers, who construct the hive, and perform all the labour necessary for its preservation, and for the well-being of the inmates. For this purpose they either collect or elaborate the following substances, namely, wax, honey, Bee-bread, and propolis; and as three of these products are more or less employed by man in art, science, or domestic economy, it will be worth our while to devote a few moments to their consideration.

Wax, the material of which the hive-cells (usually called the honeycomb) are constructed, is elaborated from the honey in the body of the Bee, and secreted in the wax-belts, situated between the rings of the abdomen, from whence the Bee draws it forth with the aid of its legs and jaws when required for the formation of the cells.

The appearance of common yellow Bee's-wax, in its original state, is of course familiar to all; it has a sweet, agreeable smell, being to some extent mixed with honey, and is then soft and easily moulded by pressure. It is converted into white or virgin wax

by bleaching in the sun, combined with a periodical application of moisture, under which influences it becomes white, translucent, and brittle; but, in order that it may retain somewhat of its pliancy, a little tallow is usually mixed with it during the process of bleaching.

Wax is composed of 80·20 carbon,
„ „ 13·14 hydrogen,
„ „ 6·36 oxygen,

and, during its exposure to the atmosphere in the bleaching process it absorbs oxygen to the extent of about 1 per cent., and parts with about the same quantity of carbon*.

It is unnecessary, and, indeed, would be almost impossible, to enumerate the various purposes to which this valuable substance is applied. In its ordinary state, it serves as an auxiliary in various trades, whilst the bleached material supplies us with some of the finest candles, which are now, however, being superseded by those made from animal and vegetable fats. It is, moreover, largely employed in medicine, forming one of the chief constituents of cerates and ointments, and by some physicians it is even administered internally.

But let us not forget its application in the arts; in the casting of busts and medallions, and, above all, in that beautiful female accomplishment, the manu-

* Achille Richard, Histoire Nat. Méd. Brande's Manual of Chemistry.

facture of artificial flowers, which almost rival nature for perfection of design and colouring; nor yet should its services to the student of anatomy be overlooked, for it is employed not only in the construction of models of the living body, but even to perpetuate the exceptional appearances of disease.

Thus we see that the humble little Bee, which is merely regarded by the majority of mankind with dread or indifference, renders us great service even in the production of this one material, which is almost indispensable to us in the arts, sciences, and domestic economy.

And now we pass on to the consideration of that most agreeable and useful substance, *Honey*, from which, as before remarked, the wax is elaborated.

Honey is secreted in the nectaries of flowers, whence it is extracted by the Bee with the aid of its delicate tongue, already described in a preceding chapter. A portion at least of the harvest or gathering is retained by the insect in its crop or paunch (to which reference was made when we treated of the digestive organs), and this is ejected into the cells of the honeycomb, on the Bee's return to the hive, to serve as a store of food in winter.

This material is so well known, that a description of it appears almost superfluous, but we may mention that pure honey is yellow, viscid, granulated, and very sweet. It contains two kinds of sugar, the one analogous to that from the grape, the other to that from the sugar-cane; it also contains

a yellow colouring matter, a little wax, gum, and, according to some authors*, an aromatic principle, and a slight trace of what appears to be acetic acid.

You see, therefore, that even *pure* honey is a very strange compound, and, possessing as it does considerable value, you will not be surprised to hear that it is rendered still more complex by adulteration. This is effected by various means, some of which render it more liquid, others more solid; and if we have recourse to the microscope, an instrument that has done so much towards exposing the dishonest practices of traders, we shall find that when honey is adulterated with sugar there is a marked difference in the form of the crystals that it contains.

Fig. 4, *a* in Pl. VIII., represents a thin crystal of ordinary honey, and fig. 4, *b* one of sugar, whilst fig. 4, *c* is a partially dissolved crystal of the latter substance that has been detected in honey†.

There are two qualities of this product: *Virgin Honey*, which is allowed to run from the comb, and, being therefore unmixed with any foreign substance, is the purest and most valuable; and another kind that is expressed from the comb, after the first has run off.

The finest description of honey, known as pure Narbonne, is produced in the central provinces of

* Richard, &c.

† The other materials employed in the adulteration of honey are potato-starch, oil, pipeclay (!), &c.

France, and is brought over to England in considerable quantities; but it is hardly needful to add that good honey may be found in every quarter of the globe.

Although largely employed in medicine, its chief use is as a condiment, and in some countries, especially in the North of Europe, it constitutes the chief element in a fermented beverage, being itself susceptible of alcoholic fermentation.

Who does not recollect the ambrosial mead of olden times, that was quaffed at the feasts of the heroes of Scandinavia, by our British forefathers, and, later on, in the so-called good old days of Queen Bess? Mead, metheglin, and hydromel (the modern name still employed), were manufactured from honey, water, herbs, and beer; the first three being fermented, and then added to the last.

Honey has sometimes been known to produce a very deleterious influence upon those who have partaken of it; and this is supposed to have arisen in consequence of its having been collected by the Bee from noxious plants. Many stories are narrated of its injurious effects, and we read in history that the whole army of Cyrus the Great was almost poisoned by some honey of which they partook in large quantities. The most authentic anecdote, however, because the most recent, is that of M. Aug. de St.-Hilaire, who, whilst on an exploring expedition in Brazil, ate a quantity of honey supposed to have been collected by a Bee called by the narrator *Apis*

lecheguana. Both he and his guide were nearly poisoned, and suffered a kind of phrenzy, the effects of which did not wear off for a considerable time. These accidents are, however, very rare, and need not alarm our readers, for European honey is a very useful and wholesome substance.

The Bees employ it in the form of what is called "royal paste," for the nourishment of the larvæ of the Queen Bee, whose treatment in this and other respects will presently be noticed.

Bee-bread is composed of the pollen of flowers moistened with honey. It is collected by the workers on their excursions, attached to the hind leg in the form of a little pellet, with the aid of the remarkable apparatus already described, and conveyed home to serve as food for larvæ as well as mature Bees. If you watch the Bees on their return to the hive, you will perceive that the little masses of Bee-bread attached to their hind legs vary in colour upon the different Bees, but not on the same insect. This arises in consequence of the several Bees collecting pollen from flowers of different colours; but we are told that in no case does the same Bee visit more than one flower at a time*.

The constitution of the Bee-bread is easily detected by mixing a little of it with water, when it will be found, under the microscope, to consist of pollen-

* The Bee certainly *visits* various species of flowers on the same journey, though it may be possible that she does not take pollen from more than one kind.

grains, some in their normal or natural state, and others that are beginning to sprout. Beyond this, we have nothing of interest to add concerning Bee-bread, and shall therefore pass on to the consideration of the fourth substance that enters into the economy of the hive—namely, *Propolis*.

This material is the viscid coating with which the buds and twigs of several plants are covered, and is collected by the Bee from these portions of the pine, fir, poplar, and birch, as well as from certain shrubs; it is conveyed to the hive in the cavity of the hind leg in the same manner as pollen.

Propolis has been found to be composed of the following ingredients:—

Resin	57 parts
Wax.....	14 „
Impurities	14 „
Acid and waste	15 „
	100

It is reddish-brown, viscid, easily softened by the warmth of the hand, and has an agreeable aromatic odour; dissolves readily in alcohol; and when combined with alkali, it forms soap*. Although it is rarely employed by man (being occasionally used in taking impressions of medallions), yet to the Bee it is an indispensable element in the construction of its hive. The insect uses it not only to fill up all the chinks and crannies of the hive, but also in cementing

* Achille Richard, Hist. Nat. Médicale.

the combs to the ceiling and sticks, and to some extent it enters into the composition of the comb itself, being applied as a kind of varnish to give strength and consistency to certain portions of the cells.

We are told by Messrs. Kirby and Spence* that, "in examining the orifice of the yellow cells, their contour appeared to the younger Huber to be besmeared with a reddish varnish, unctuous, strong-scented, and similar to, if not the same as propolis. Sometimes there were red threads in the interior, which were also applied round the sides, rhombs, or trapeziums. This solder, as it may be called, placed at the point of contact of the different parts, and at the summit of the angles formed by their meeting, seemed to give solidity to the cells, round the axis of the longest of which there were sometimes one or two red zones. From subsequent experiments, M. Huber ascertained that this substance was actually propolis, collected from the buds of the poplar. He saw them with the mandibles draw a thread from the mass of propolis that was most conveniently situated, and, breaking it by a sudden jerk of the head, take it with the claws of their fore legs, and then, entering the cell, place it at the angles, sides, &c., which they had previously planished. The yellow colour, however, is not given by the propolis, and it is not certain to what it is owing. The Bees sometimes mix wax and propolis and make an amalgam, known to the ancients, and called by them *mitys* and *pisso-*

* 'Entomology,' new edition, p. 280.

ceros, which they use in rebuilding cells that have been destroyed, in order to strengthen and support the edifice."

Bees have been known to make a most remarkable use of propolis; namely, to render innocuous the bodies of intruders into the hive, who have fallen victims to their stings. There is one case mentioned of a mouse which they had slaughtered in the hive, and completely cased in this substance; but the most wonderful application of the material, and at the same time the strangest evidence of the instinct of the creature, is found in the anecdote, that they once soldered down the shell of an unfortunate snail that had crept up the side of their hive; "thus fixing him (as an essayist in the 'Quarterly Review' has wittily remarked) as a standing joke, a laughing-stock, a living mummy, like Marmion's Constance, 'alive within the tomb' [for a snail, though excluded from the air, would not die]; so that he who had heretofore carried his own house was now made his own monument*."

Having thus briefly referred to the properties of the materials collected by the workers for the construction and maintenance of the hive, as well as for the nourishment of its inmates, let us now consider the nature and operations of the little labourers themselves.

The Worker-bees are, as before stated, females in

* 'The Honey Bee,' Murray, 1852, a most entertaining little pamphlet.

whom the reproductive organs are but partially developed, and, as they are thereby rendered unfruitful, and consequently unable to assist in peopling the hive, their whole time is devoted to collecting the materials already described, constructing the comb, nourishing the young, attending upon the Queen, defending the community; and, wonderful to relate, in providing for the cleanliness and ventilation of the hive.

According to Huber, there are two kinds of workers. The first he terms "*Abeilles cirières*," or wax-makers, who elaborate the wax, and lay the foundations of the cells; the second, "*Abeilles nourrices*," or Bee-nurses, who continue and complete the formation of the cells, collect honey, &c., feed the young, and perform the other labours of the hive.

And now let us consider that most wonderful instinctive faculty exhibited in the construction and architecture of the waxen cells which constitute the Bee's habitation; and when we examine the *modus operandi* of the various kinds of workers, we shall find that they enter upon their labours as systematically, and apparently with as perfect design, as do the most experienced architects and builders.

First of all, a number of *wax-makers* having assembled for the purpose, one of them draws from the wax-pockets or belts situated between the rings of her abdomen, where the wax is secreted, a certain quantity of this material, which she moistens with a fluid from her mouth, and then moulds into the form

of a thin narrow ribbon by repeated workings with her feet, jaws, and delicate tongue. The particles of wax thus obtained she attaches to the vault of the hive, and then proceeds at once to fabricate and apply a second and third, and so on (adjusting them in the direction the comb is to take), until all her wax is exhausted, when she disappears and makes way for a second labourer. The repetition of this operation by one Bee after another gradually forms "a little wall of wax with uneven surfaces, five or six inches long, two lines high, and half a line thick, which descends perpendicularly below the vault of the hive*." This done, the operations of the *nurse-bees* begin, the wax-makers leaving to them the task of completing the construction of the comb. They at once proceed to excavate the cells on both sides of the wall, *drawing out*† the wax in the required direction, so that one partition serves as the base of two cells.

Meanwhile the wax-makers continue to elaborate that material, and add to the foundation-wall, leaving their comrades to design and construct the cells; until the comb, which consists of a double series of hexagonal cells, placed, as it were, back to back, is completed.

We are now considering what was until recently regarded as the most wonderful trait in the nature of

* The operation is described with great minuteness in Kirby and Spence, p. 277; partly extracted from Réaumur, v. 424. See also note on page 86 of this work.

† Or, according to some observers, *building up* the walls with the excavated wax.

the Bee; for almost miraculous powers have been attributed to the insect to enable it to construct these cells. It has been proved by able mathematicians that the form which they are made to assume requires the least amount of material consistent with strength; and that if any other figure had been substituted for the hexagon, or any other angles than those now presented by the sides of the cells, it would not have been possible to group so great a number of the latter in the same space; for we are told that although circular cells might have better suited the shape of the Bee's body, yet the waste of space and material would, in that case, have been considerable.

On the other hand, however, it has been stated that the design of these cells is not *at first* hexagonal, but, according to some observers, it is *pentagonal*, whilst others declare it to be *circular* in the first instance; all agree, however, that as the cells progress, they assume the most appropriate and economical form, namely the hexagon.

Numerous have been the surmises as to the guiding principle that causes the Bees to construct their cells after this model, and, although it is still a controverted question, we shall attempt briefly to review the various theories that have been propounded on the subject.

Some naturalists believe that the Bee possesses an innate instinct which teaches it that this is the most economical and desirable shape for its cells, and, to show how far this instinct transcends the calculating

powers of man, they point to the fact, that the most talented mathematicians have avowed themselves unable to substitute a more suitable design than this particular form of hexagon; indeed, they have acknowledged the Bee as their preceptor, and adopted this as the most perfect shape. But there are other observers who declare that there is nothing at all remarkable in the fact of the cells assuming the hexagonal form, inasmuch as they are normally or naturally cylindrical*, and acquire the former shape only in consequence of the pressure caused by the multitude of bees engaged upon them.

This assertion, however, is at once controverted by the advocates of the "instinctive" theory, who declare that, as only one bee at a time works upon each cell, and then makes way for another, the pressure cannot exist, to which the change of shape is attributed. A third theory propounded by naturalists is, that the peculiar form of the cell is attributable to the disposition of the simple eyes of the insect; that "these eyes are placed in such a position as to enable them to work within such a range as to give the walls of their cells 120 degrees†." Now, it is questionable whether the simple eyes of insects are employed in viewing near objects; and Mr. Lubbock, one of our most able entomologists, states that the Bees inva-

* Amongst others, W. B. Tegetmeier, "On the Formation of the Cells of Bees."—Meeting of Brit. Assoc. Oct. 1858.

† Mr. Ellis "On the cause of the instinctive tendency of Bees to form hexagonal cells."—Meeting of Brit. Ass. Oct. 1858.

riably work in the dark: besides, the compound eyes, from the shape of their facets, are far more likely than the simple ones to receive impressions that would lead to the formation of hexagonal cells; this theory is therefore by no means probable.

And lastly, Dr. Lankester, another of our most talented naturalists, has expressed the opinion that these cells are formed hexagonally in consequence of an impression made upon the antennæ, or some other organ of sense*.

Well, then, you will be disposed to ask, which of these theories, apparently so much at variance, is the correct one? If the cells are not normally hexagonal, and are not made so by an innate instinctive power of the animal; if the change in shape from the cylindrical to the hexedral form is not brought about by the pressure of the Bees, and the disposition of the simple eyes has nothing to do with it, pray to what cause is this wonderful phenomenon to be attributed?

We should be glad if we could answer this question finally and satisfactorily, but *that* we cannot do; and, indeed, if such observers as Réaumur, Spence, Darwin, and Tegetmeier, all of whom have carefully watched the habits of the insect, cannot agree upon the subject, it is hardly to be expected that *we* should decide the controversy. It is, however, our business to compare these theories, and a little reflection, free

* See report of discussion on the foregoing paper by Mr. Ellis.—'Athenæum,' No. 1616, Oct. 16, 1858.

from bias or prejudice, aided by the consideration of other natural objects and phenomena, may perhaps lead us to some useful conclusion on the subject.

First, then, all the naturalists whose opinions we have quoted agree that the design of the cells is not originally hexagonal, but that (with the exception of certain cells at the side of the comb and around the queen-cell) they eventually become so. Next, they agree with mathematicians, that, after the circle, this form of cell encloses the largest space with the smallest amount of material; and every one is acquainted with the extreme tenuity of the cell-walls of the honey-comb. Now the real question is—*are these cells normally cylindrical, and do they of necessity resolve themselves into hexagons when the neighbouring ones are built up against them? or, do the Bees begin by making them irregularly pentagonal, and cause them gradually to assume the hexagonal shape as they progress?*

In describing the eye of the Bee, we showed that where a number of circles or spheres are *developed* in close contact, they resolve themselves into perfect hexagons. Turning to other natural objects, we observe in the tissue of plants, that when the circular cells become differentiated, and take the form of tubes, growing together with the neighbouring vessels of similar shape, they also assume the hexagonal type, and their structure then greatly resembles the honey-comb. This we find exemplified not only in the higher plants and animals, but also most beautifully

in some of those mysterious forms, the Diatomaceæ, where the siliceous cases present the perfect honeycomb structure. Again, mathematicians of undoubted ability tell us that the hexagonal cells of the honeycomb exhibit precisely the form that would result from the close contact and adhesion of a number of circular or cylindrical bodies of a soft, flexible substance; and lastly, an examination of the honeycomb shows us, that where a cell is terminal, that is to say, where another is not added to it, at the terminal side it is not hexagonal, but irregularly round.

Now it certainly appears to us to be going a *little* out of our way if we seek to attribute the hexagonal shape of these cells to the result of an instinct in the Bee that transcends the calculating powers of the ablest mathematicians, when we find by accumulated evidence that the natural form assumed by a series of circles when brought into close contact would be that of the cells of a honeycomb; and not only are the walls of these cells *remarkably thin*, but, when newly wrought, they are exceedingly ductile and tenacious*, and consist of two layers†. The appearance of these two layers, when examined with a low microscopic power (after cutting away the outer rim of the cell, which is always rather thick and circular), is such as to suggest the idea that the cells themselves are constituted of circles or cylindrical tubes of

* Kirby and Spence, p. 276.

† Kirby and Spence, p. 274, *note*. From 'Memoirs of the Wernerian Society.'

extreme tenuity that have been brought into close contact.

Looking, then, at the foregoing circumstances, and considering also that all animals construct tubular or circular habitations*, we should be disposed to agree with those naturalists who regard the hive-cells as normally cylindrical; and certainly the mathematical precision with which they appear to be framed inclines us to attribute the hexagonal form to mechanical rather than to instinctive causes. At the same time, we are not at all wishful to rob our little worker of any merit to which she is entitled; and we feel equally satisfied, from the powers of observation possessed by the Bee, and the regularity with which her natural operations are repeated, that much of the uniformity of these cells is due to the circumstance, that, guided (as Dr. Lankester says) by external impressions, she lends a helping hand to inorganic nature, and co-operates with her laws†.

As the foundation wall of wax, from either side of which the cells are excavated, is suspended perpendicularly from the vault of the hive, it follows that the

* We purposely omit to notice the statement of a few naturalists who pronounce the *design* of the Wasp's cell to be hexagonal. What applies to the Bee applies equally to the Wasp; and some Wasps build circular cells, or at least cells that are round at the outside of the nest.—See Rymer Jones, 'Nat. Hist. of Animals,' vol. ii. p. 229 (1842).

† In his work on the 'Origin of Species,' Mr. Darwin describes some experiments tried by him in connexion with the method by which Bees construct their cells;—these experiments prove satisfactorily that they are at *first* circular.

comb is composed of a double series of *horizontal* cells placed end to end, and divided by a thin partition of wax (Pl. VIII. fig. 5). But these cells are not all of the same dimensions; for the Drones, being larger than the Workers, require a larger cradle in their infancy or larvahood, and the Bees therefore construct a sufficient number of cells suitable for their reception about the centre of the comb.

The transition from the smaller *worker-* to the larger *drone-cells* is not, however, sudden, and we find a series of what are termed *intermediate cells*, of a gradually increasing diameter, so that our little architects appear in all things to proceed in an orderly and systematic manner.

A strange deviation from the ordinary hexagonal cell (and another piece of evidence in favour of the cylindrical theory) is presented by those destined for the reception of the royal family, commonly known as *queen-* or *royal-cells*.

These differ from the rest in size, form, and position, occupying as much space at least as half-a-dozen worker-cells. They are of an irregular oval or pear-shape, made up of a kind of mosaic work of coarse wax, and, instead of being horizontally disposed, they are suspended almost perpendicularly, with the aperture downwards, against the side, or more commonly at the lower part of the comb (Pl. VIII. figs. 5 & 6, *q c*). These three kinds of cells, the worker-, drone-, and queen-cells, are employed by the Bees for the purposes of incubation and rearing of the young, to

be described hereafter; and the two first-named, or cells similarly constructed, serve also for the storing of honey.

Let us now rejoin our little workers in their various occupations.

It is unnecessary to accompany them in their search for honey, for we referred to this portion of their daily task whilst treating of the materials that they collect; and during our investigation of the Bee's organs and members, we had a favourable opportunity, not only of examining that part of its digestive system in which honey is temporarily stored before it is regurgitated into the cells, but also of admiring the beautiful oral apparatus, especially the tongue, by which it is aided in the gathering of nectar. We also closely scrutinized that portion of the hind leg which serves as a basket for the conveyance of pollen, or bee-bread, and shall now draw your attention to a most remarkable and interesting phenomenon connected with this part of the worker's employments. Not only does the bee in her excursions gather sufficient of the substance just named to fill her pollen-baskets, but, being covered all over with long hairs, the germs of the various flowers that she visits adhere to her, and her whole body becomes charged with them.

Whether or not the matrons of the hive relieve her of this additional store of provender, as they do on her return home of the bee-bread contained in her pollen-baskets, we are unable to say; but one thing is cer-

tain in regard to this accidental accumulation of pollen: the Bee, in passing from the corolla of one flower to that of another, covered with the dust that constitutes the propagating elements of plants, brushes off a portion of the pollen grains, and, depositing them undesignedly upon such as require them for the purposes of generation, she, in common with many other insects, becomes the unconscious means of promoting the reproductive process in the vegetable kingdom.

But what is most remarkable in this phenomenon is, that during her journeys in search of food her visits are always confined to one species of flower only (as we stated in treating of bee-bread), so that, to use the words of Mr. Kirby, "they avoid the production of hybrid plants from the application of the pollen of one kind of plant to the stigma of another."

Now you will understand what was meant by the remark made at the commencement of this chapter, that the Bee "*sows* and reaps," for she actually performs both operations at the same time. And is not this another admirable example of the wisdom with which the Creator has economized the labour of the lower animals, and another striking evidence that no creature has been formed in vain? Let any sceptic throw discredit on the assertion, and you may at once point to a multitude of those insects that he regards with aversion or indifference, believing them to be utterly useless, or even noxious; and draw his attention to the fact, that, unknown to him, they are the unconscious means of adorning and beautifying our

parterres, gardens, and country hedges, or of adding to the fruitfulness of our orchards.

It is indeed most interesting to witness the busy tide of life, even at the entrance of the hive. Stand and watch for a few moments, and you will see worker after worker return from her journey laden with bee-bread*, attached in little pellets to her hind legs, which she drags laboriously after her into the hive when she has alighted upon the board whereon it rests.

And just as the stream of laden bees pours continuously into the hive, so is there a constant succession of unembarrassed workers issuing from the entrance, who wing their flight in every direction in search of blossoms, whence to extract the store of materials requisite for their domestic economy.

Should you not be afraid of the tiny weapons of the little workers, but venture to approach and peep into the entrance of the hive†, you will perceive a number of bees standing within, and vibrating their wings with such rapidity that these members are rendered almost invisible. And what think you, reader, is the object of this laborious employment? Why, the bees are punkah-bearers, or whatever you please to call them, creating and conducting a current of fresh air into the recesses of the hive, for the purpose of reducing or equalizing its temperature; and

* Réaumur estimates at the rate of 100 per minute.

† The best safeguard is to hold in your hand a bunch of sweet-scented herbs or flowers.

you will now see the necessity that exists for that beautiful apparatus, described elsewhere (Pl. V. fig. 5, and Pl. VI. fig. 4), by means of which the bee is enabled to lock together its fore and hind wings, in order to render them impervious to the atmosphere.

What a lesson of prudence does the little Bee teach those who themselves dwell, or permit others to do so, in close, confined habitations, into which the free air of heaven cannot gain admittance; who sit in apartments, or move about in saloons with windows and doors closed, and the gas and fire blazing at their full height, without a single aperture in the apartment by which a little fresh oxygen may be admitted to renew the exhausted and vitiated atmosphere!

Instinct indeed! Is it not a pity but what some of us might barter a little of our boasted reason against this inferior nature of the humble Bee?

Not only do the workers keep the hive cool and of an equal temperature, but, without requiring a "Nuisance Removal Act" or a Board of Health to direct their operations, they are careful not to deposit refuse of any kind whatever in the hive; nor do they allow any to remain that has been accidentally left there. If some creature should have found its way into the hive, and, as is often the case, have fallen a victim to their stings, they at once proceed (without the fostering care of a Burial Board) to encase it in propolis, as we already mentioned in treating of that substance, so that no effluvia may arise from the carcase.

The workers are said to be adepts in the construc-

tion of fortifications, to keep out enemies from the hive; and we cannot better illustrate this remarkable property than by quoting from the pages of Kirby and Spence the following account, by Huber, of their operations in this respect:—

"To defend themselves from the death's-head hawk-moth, they have recourse to a different proceeding. In seasons in which they are annoyed by this animal, they often barricade the entrance of their hive by a thick wall made of wax and propolis. This wall is built immediately behind, and sometimes in the gateway, which it entirely stops up; but it is itself pierced with an opening or two, sufficient for the passage of one or two workers. These fortifications are occasionally varied; sometimes there is only one wall, as just described, the apertures of which are in arcades, and placed in the upper part of the masonry. At others, many little bastions, one behind the other, are erected. Gateways, masked by the anterior walls, and not corresponding with those in them, are made in the second line of building. These casemented gates are not constructed by the Bees without the most urgent necessity. When their danger is present and pressing, and they are, as it were, compelled to seek some preservative, they have recourse to this mode of defence, which places the instinct of these animals in a wonderful light, and shows how well they know how to adapt their proceedings to circumstances. Can this be merely sensitive? When attacked by strange bees, they have recourse to a similar

manœuvre; only in this case they make narrow apertures, sufficient for a single Bee to pass through."

It would be impossible to include within the limits of this little treatise a detailed account of all the duties and employments of the Worker Bees; and of some of the most important, such as feeding and attending upon the young, we shall be able to treat more appropriately when we come to speak of the Queen Bee, to whom our attention will next be directed.

Then, too, we shall have an opportunity of considering one or two more traits in the natural history of the Drones, as well as many remarkable phenomena by which order is maintained throughout this wonderful little commonwealth.

CHAPTER VI.

THE QUEEN.—HER METHOD OF LAYING EGGS.—WONDERFUL PHENOMENA ACCOMPANYING THE INSTINCTIVE DEPOSITION OF THE EGGS OF WORKERS, DRONES, AND QUEENS IN THEIR RESPECTIVE CELLS.—DZIERZON'S DISCOVERIES AND THEORIES.—SIEBOLD AND OWEN ON THE LAYING OF UNFERTILIZED OVA.—INTERESTING EXPERIMENT BY HUBER, AND REVIEW OF THE THEORIES OF DZIERZON, SIEBOLD, AND HUBER.—PARTHENOGENESIS, OR POWER OF THE VIRGIN QUEEN TO PRODUCE PERFECT OFFSPRING.—THE LARVA; ITS ORGANIZATION.—METAMORPHOSIS INTO THE PUPA AND IMAGO.—OPERATIONS OF THE NURSE-BEES DURING THE TRANSFORMATION.—REFLECTIONS ON THE DEVELOPMENT OF THE BEE AND THAT OF THE MAN.—OPERATIONS OF WORKERS AFTER THE BEES LEAVE THE CELLS.—BIRTH OF YOUNG QUEEN.—UNNATURAL CONDUCT OF THE PARENT.—VOGT'S INTERESTING ACCOUNT OF A COMBAT BETWEEN TWO QUEENS.—THE DRONES.—BEE COURTSHIP AND MATRIMONY—ARTIFICIAL PRODUCTION OF A QUEEN BY WORKERS.—PRINCIPLE UPON WHICH THEY OPERATE.—SUMMARY.

For the better comprehension of the history of the Queen Bee, and of her relations to the hive, we must commence at a period when her life is already somewhat advanced, and state that the fertile queen passes the winter in the hive along with a number of workers, but without drones (who are, as before mentioned, slaughtered on the approach of winter). Should the swarm be transferred to a new hive, the queen begins

to deposit eggs capable of producing young ones, as soon as cells are prepared for their reception. First, she deposits worker-eggs in worker-cells; then drone-eggs in drone-cells; and finally, she oviposits in the royal cells one or more eggs from which there proceed larvæ that become queens, *one* of whom alone is permitted to live and govern the hive, whilst the old queen takes her departure with a "swarm" composed of drones and workers.

This act of depositing the various eggs in their respective cells the queen performs by introducing the hinder part of her body into the cell, and there dropping the egg,—an operation which, when duly considered, cannot fail to excite the astonishment of every reflecting observer. How does the queen know which are worker-, which drone-, and which royal-cells? And, suppose that her instinct suffices to guide her in this respect, how is it possible that she can predict the sex or nature of the young that will proceed from the ova she is about to deposit?

As regards those deposited in the queen-cells, the mystery is not so inexplicable; and the difference between the ordinary worker and the royal insect is easily accounted for by the enlarged dimensions of the cell, the difference in its position (being vertical instead of horizontal), and the changed character of the food, all of which, no doubt, aid in the development of the reproductive organs, and which constitutes the chief difference between the queen and worker; but still the problem remains unsolved—how is it

that eggs producing females are in every case deposited either in the queen-cells, which are larger, or, what is still more remarkable, in the worker-cells, which are *smaller* than the drone-cells, whilst in the last-named, *male* eggs are invariably placed?

All the information that is furnished to us in this respect by the present state of our knowledge goes no farther than to show that this wonderful attribute of the Queen Bee is not accidental, but that her actions are directed by some definite law, for the fulfilment of which her organs of reproduction are suitably framed; and we must ask you to refer once more to this portion of the anatomy of the Queen Bee (Pl. VIII. figs. 1, 2, 3), where you will perceive the two ovaries filled with eggs, and (fig. 2, *s*) the little pocket attached to the oviduct, in which, as before stated, the male elements are stored that fertilize the eggs in their passage through the oviduct.

Although the consideration of these organs may perhaps not be suggestive of anything remarkable to you, yet an examination of them led to the discovery, by a famous German bee-keeper and naturalist, Herr Dzierzon, of Carlsmarkt, of the following wonderful phenomenon, namely, that "all eggs that come to maturity in the two ovaries of the Queen Bee are only of one and the same kind, which, *when they are laid without coming into contact with the male semen, become male Bees; but, on the contrary, when they are fertilized by male semen, produce female Bees**."

* Siebold, 'On the Parthenogenesis of the Honey Bee,' 53.

But, reader, if you are at all of a sceptical turn of mind, you may be disposed to shake your head, and accord to such a wonderful discovery only a smile of incredulity. "Herr Dzierzon," you might say, "may make this assertion with impunity, for it would be as difficult for any one else to *disprove* as it would be for him to *prove* his theory."

His theory is, however, a *fact*, and one that *has* been proved, not by himself, but by the greatest German naturalist of the day, Professor Siebold, and accredited by that most talented and reliable English physiologist, Professor Owen; and we shall briefly state the means employed by the former to test the accuracy of Dzierzon's theory. He examined with the aid of the microscope the fresh-laid eggs of drones and workers, and, by careful manipulation, he succeeded through this means in confirming the discovery made by Dzierzon, for he satisfied himself by ocular demonstration that in *no case* is the *drone-egg* fertilized, whilst traces might nearly always be found of the male element in the *worker-egg*.

Nor must it be supposed that he entered upon his investigations with any preconceived notions *in favour* of the theory, or drew his conclusions from a single experiment only. On the contrary, he commenced his observations a sceptic, and was convinced only after examining with great care seventy-nine eggs, namely, twenty-seven male and fifty-two female.

These eggs he obtained at the apiary of Herr von Berlepsch at Seebach, which place he visited for this

special purpose, and in thirty out of fifty-two fresh-laid worker-eggs, examined by him "with the greatest care and conscientiousness*," he obtained a positive result in favour of the theory, detecting the male element in some instances still active; whilst the examination of twenty-seven drone-eggs, in *not one* of which he could find the slightest trace of the male element, served completely to confirm his observations and Dzierzon's theory.

And now, suppose we take it for granted that eggs may be deposited by the Bee that will produce either drones or workers, according to the circumstances just referred to; we are tempted to inquire further, "does the volition of the Bee exercise any influence over the kind of egg about to be deposited, or is it the result of mere mechanical action?"

Dzierzon believes also that the queen possesses the power either to deposit her eggs unfertilized, that is to say, *to lay drone-eggs*; or of fertilizing *and converting them into worker-eggs at her will*; and this idea is countenanced by Siebold, who states that he has discovered voluntary muscles for the purpose, and he considers it very probable that the Bee may be guided in her operations by feeling the dimensions of the different kinds of cells during the act of oviposition.

Here, however, it would appear that the two great German naturalists have hastened rather prematurely to a conclusion; for, whilst the former theory is not only confirmed by direct observation, but accords

* Siebold's 'Parthenogenesis.'

with all that had been previously known to apiarists, the theory of voluntary oviposition, or rather of voluntary *fertilization*, has not been confirmed by observation, but is, as we shall presently show, at variance with the experience of the most accurate observers.

Huber, who has bestowed as great care upon the consideration of the *habits* of Bees as Siebold and others have upon their anatomy, states that, although "the instinct of the queen directs her to deposit worker-eggs in worker-cells," yet when he "confined one during her course of laying worker-eggs where she could come at male cells only," she did not commence laying drone-eggs, but "she refused to oviposit in them, and, trying in vain to make her escape, they at length dropped from her."

Now, unless you feel disposed to extend to her that waywardness which is sometimes regarded as characteristic of the fair sex, it would be clear that, *if* the Queen-bee possessed the power of voluntary fertilization, she would at once, under the pressing impulse to oviposit as described by Huber, have adapted her eggs to the cells that presented themselves. This, however, she did not do; but it appears that her instinct prompted her so strongly to lay worker-eggs, that, trying to make her escape from the drone-cells, "they dropped from her."

From a careful consideration of this and other experiments, we are disposed to think that, although the queen is enabled by her instinct to find the proper cells for her respective ova, and, as it would appear,

the *negative* power of refusing to oviposit in inappropriate cells, yet she seems to have stated periods for depositing, first one class of eggs, and then another; and from this course of proceeding it appears she cannot deviate*. Although, therefore, we are not yet able fully to explain the nature of this wonderful phenomenon in the Bee, you will perceive that it has revealed to us one of the most remarkable facts in natural history; namely, that the egg is capable of producing living young without *fertilization*.

"But stay!" you will mentally exclaim; "if the unfertilized eggs of the insect produce drones or males, why could not a virgin queen give birth to young drones?" Let not this reflection, reader, cause you to relapse into scepticism, but believe us when we tell you that she really does possess this power (and not she alone, but also other insects belonging to the *Lepidoptera*, or Butterfly races); and the young that proceed from these virgin eggs are not imperfect or transitional forms, such as the so-called "*nurses*" of aphides†, but perfectly de-

* Having arrived at this conclusion after an unprejudiced consideration of various statements concerning the properties of oviposition in the Queen-bee, and wishing to guide others aright, it is only proper to add, that an experiment described by Siebold ('Parthenogenesis,' p. 90) *to some extent* supports Dzierzon's theory of voluntary oviposition; but it also confirms the opinion expressed above, that the Queen-bee is *impelled* to lay a certain kind of eggs for a certain period, and then changes her course of proceeding, always, however, laying the various kinds in the same order or succession.

† Carpenter's 'Zoology,' vol. ii. p. 189.

veloped male Bees. This fact has been repeatedly confirmed by observation and experiment; and although it rarely occurs, and may therefore be regarded as the exception that proves the rule with which it is at variance (namely, that a union of the sexes must take place before another of the same species can be produced), yet it suffices to derange our preconceived views in regard to what we call the infallible laws of nature, and affords another striking evidence of the Creator's power, and the infinitude of His resources.

In the Mollusca and some of the lowest animal forms, we often find the two sexes united in one individual* capable of producing young; but here we have a still more wonderful manifestation of power, namely, an insect of *one sex*, highly organized both physically and mentally, bearing living young without the cooperation of the other sex. Does this not teach us in unmistakeable terms that *nothing* is impossible to God? and that—

> "These lower works that swell His praise
> High as man's thoughts can tower,
> Are but a portion of His ways,
> The hiding of His power"?

Having been thus imperceptibly led from the consideration of the three different varieties of inmates

* This phenomenon is found also in the Bee. In the 'Entomologist's Annual' for 1859 there is depicted and described a hermaphrodite Bee, of which one side bears all the characteristic features of the male, and the other those of the female.

in the hive, to the almost miraculous powers of the queen in producing and depositing in their respective cells the eggs from which they proceed, we shall now quit the Bee-mother for a time, to devote a portion of our space to her young progeny, and refer to the remarkable phenomena that accompany the development of the three forms, the worker, drone, and queen, as exhibited in their various stages of larva, pupa, and imago.

In the first stage of its existence, that is to say the larval state, after it has proceeded from the egg, the young Bee resembles a minute, yellowish white worm, exhibiting to the naked eye no trace of external organs or members. The lens, however, reveals an imperfect oral apparatus, or mouth, for the reception of food (administered to it by the workers whilst it still remains in the cell), and on the lower lip a pair of spinnarets, with which it spins its cocoon preparatory to assuming the second or pupal state.

The body of the larva is divided into thirteen rings, and a row of spiracles or breathing-holes may be detected on either side of the body, one situated upon each ring.

It is, however, not a very attractive object, having the appearance of a great over-fed maggot (Pl. VIII. fig. 7, represents one magnified about 6 or 8 diameters), and the wonder is that from such an imperfect and ungainly form there should, in the course of a few days, be developed the perfect little Bee, with all its organs and members; eyes simple and

PLATE VIII



Fig. 1.

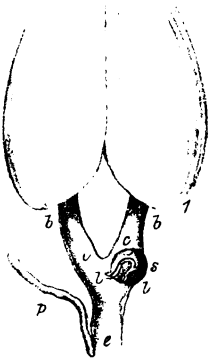


Fig. 2.

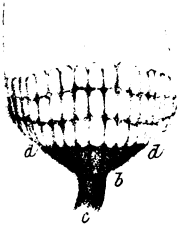


Fig. 3.

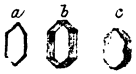


Fig. 4.

Fig. 5.

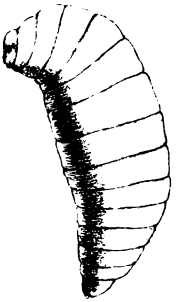


Fig. 7.

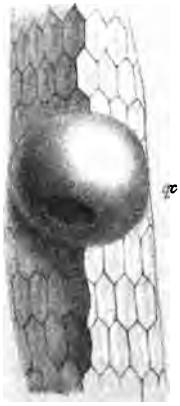


Fig. 6.

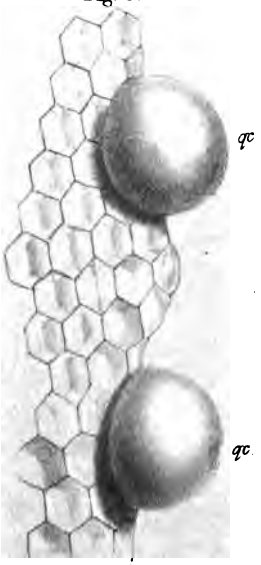


Fig. 8.



Hicks & Samuelson, del?

G.H. Ford, lith?

Ovaries of Queen; Larva, Pupa of Worker; Ordinary & Royal Cells.

John Van Voorst, London

compound; wings, legs, and all the other portions of its external organization.

In the metamorphosis from larva to pupa, a constriction takes place between the first and second, and another between the fourth and fifth rings of the body; the first becoming transformed into the head, with its antennæ, oral apparatus, &c.; and the second, third, and fourth into the thorax, with its accompanying members; whilst the remaining rings constitute the abdomen. The large compound eyes at first resemble two small dark streaks, one on each side of the head, and even at this early stage their composite structure is discernible under the microscope; the various members of locomotion do not grow out of the body, but appear upon the surface, moulded, as it were, under the manipulations of the invisible hand of Nature.

At first they remain adherent to the body throughout their whole length; but as the metamorphosis proceeds they become detached, and at length the yellowish pupa (for it retains the characteristic colour of the larva for some time after the change has begun) assumes a dark-brown hue, the external skin becoming hardened, and it then presents the appearance depicted in the illustration (Pl. VIII. fig. 8). Simultaneously with these external changes in the Bee's structure, a transformation is taking place in its internal anatomy. This in the larva is of the simplest kind, being adapted to the habits of the insect, and ministering to its rapid growth.

The digestive organs are the most prominent, but even these consist chiefly of a large intestine, and they do their work so efficiently, that an immense quantity of fat is stored up in the body of the little larva as raw material, of which the more complicated organs of the imago are built up.

To these it is needless to refer, as they have already been described in detail; quitting, therefore, the consideration of these mysterious changes that are veiled from our sight, we shall now direct our attention to the active operations of the workers in connexion with this part of the Bee's history.

"The poor worm usually lies curled up in a half-circle in its cell, and the only symptom of life that it exhibits is by scratching with its mandibles against the cell-wall, as an intimation that it requires nourishment. It, however, becomes the tenderest object of solicitude on the part of the workers; they clean and rub it, endeavour by their sonorous hum to cheer it in its solitary confinement, and constantly supply it with infant food (bee-bread), which they manufacture from honey and pollen, and offer to the little nursling at the point of their ligula, or tongue. The whole arrangement of the attendance resembles that in a foundling hospital; the watchful nurses wander from crib to crib, from cell to cell, offering food to the little inmates, stroking them with their antennæ, and fondling them with their delicate organs of nutrition*".

* Vogt, 'Untersuchungen in den Thierstaaten.'

After they have been thus treated for a few days, the nurses discontinue the supply of food, and close up the orifice of the cell with wax. This operation they perform by applying a series of concentric rings of gradually decreasing circumference, one within another, until there is nothing left but a small hole in the centre, which is then blocked up with a particle of wax. As soon as the cell is closed, the inmate sets to work and spins a cocoon of silk (which the *queen*-larva accomplishes in about twenty-four hours, the *worker* in thirty-six), and then rests for two or three days. At the end of this time it assumes the *pupa*-form, undergoing the metamorphosis from the worm-structure to that of the insect (already described); and when this is complete, the *imago*, or fully-developed insect, first frees itself from its silken envelope, and then, forcing open the lid of its prison-house by means of its head and mandibles, makes its escape a perfect Bee.

The time occupied from the deposition of the egg to the final appearance of the insect is, for the queen sixteen days, for the worker about twenty, and for the drone twenty-four days.

"How wonderful is this circumstance!" says M. Vogt*. "Here, too, in the Animal Kingdom, the members of the royal family have the privilege of attaining their majority, and exercising their legal rights, before their fellow-creatures. For the education of the poor worker, who must indeed learn to collect honey

* 'Untersuchungen in den Thierstaaten.'

and pollen, construct the comb, and nurse the young; for the development of such a poor faithful, obedient wight, more time is needed than for the head of the State, on whom devolve the serious cares and responsibilities of government. Has mankind learnt this lesson from the Bee?"

But the labours of the worker in regard to the tending of the brood do not end here. After the young insect, be it worker, drone, or queen, has effected its escape, a number of busy nurses at once set to work and prepare the vacated cell for the reception of another egg. First one enters, and, searching for the pupa-case, drags it forth and carries it away to the entrance of the hive; a second follows and brings away the exuviæ from the larva; and then other succeeding bees clear off every particle of refuse, leaving only a portion of the silken cocoon, which gives additional strength to the cell.

Returning now to the history of the queen, we are told that, during her progress from cell to cell for the purpose of oviposition, she is accompanied by from four to twelve workers, who provide her with honey, and, watching all her movements, take care that she lays only one egg in each cell; or in case she should deposit more, as sometimes happens, they remove all but one, and place them elsewhere *. She usually lays from two to six eggs in succession, and then rests awhile; and according to Reaumur she will thus deposit about 200 eggs in one day. The total num-

* Kirby and Spence.

ber laid by a single queen in one season is variously estimated at from 50,000 to 100,000 eggs.

Let us now suppose the spring to be somewhat advanced, and that in the month of May the queen has deposited about 10,000 to 11,000 worker- and drone-eggs. At this time the workers construct half-a-dozen royal cells, already described, and her Majesty proceeds forthwith to deposit in them the necessary eggs *.

The usual term of sixteen days having now expired, the guardians of one of the royal cells receive intimation, by the movement within, that a new monarch is about to make her appearance, and immediately the intelligence flies from Bee to Bee, and they crowd around the cell in order to welcome the stranger. The queen-mother approaches also, accompanied by her body-guard.

"Dear me! how interesting!" we can almost hear you exclaim, reader; "to welcome the little stranger, no doubt?"

No, not to welcome her offspring, but, *incredibile dictu!* with the murderous intention of attacking and slaughtering her as a rival!

In this design, however, she is foiled by the workers that have gathered around the royal cell. These cover its entrance, and keep the young queen a close prisoner; if necessary, blocking up the opening of the cell with wax until the old queen shall have disap-

* Female ova, be it remembered, which, in hexagonal cells, would have produced workers.

peared, and feeding the young one with honey during her imprisonment.

In the hive of bees, as in the hives of men, two Cæsars, or rather, in the former case, two Czarinas, cannot exist at one time; and when the old queen finds that her hateful rival is beyond her reach, she ceases to oviposit, and, wandering about the hive in a state of great excitement, she at length takes her departure in search of a fresh habitation, accompanied, in a full hive, by about 1000 drones (who are said to lead the way), and ten times that number of workers. This new colony, well known to us as the "swarm," is received by bee-keepers in an empty hive, where the workers at once proceed to construct waxen cells and perform their ordinary avocations, whilst the queen resumes the work of oviposition.

But let us now return to the old hive, where the young queen holds undisputed possession, and this she renders doubly sure by at once proceeding to the cells that contain her younger sisters, and with her sting mercilessly destroying them before they arrive at maturity.

Sometimes, however, it happens that two young queens make their exit simultaneously from their respective cells, and by a curious instinct the old queen is then diverted from her purpose of infanticide, and at once takes her departure with her attendant swarm.

For the sequel, we must once more refer to the pages of Vogt, for we are sure you will agree with us

that the account is graphic, interesting, and morally instructive :—

"The Bees that remain after the swarm has taken its departure divide into two parties, which marshal themselves around the respective queens, and then march against one another within the hive itself.

"Presently the armies approach one another from either side; they meet face to face; and what follows? Will the onslaught at once begin? This would indeed be the case if they were human beings, of whom thousands would rush to their fate, and streams of blood would be shed for the sake of one ruler.

"But no! the Bees are wiser; what care they, with their constitutional *régime*, whether the reins of power be held by a member of the house of Hapsburg or of Hohenzollern! 'Let the ambitious aspirants decide the struggle for supremacy by single combat!' So say the Bees, and they look on quietly whilst the duel is being fought, quite content to tender their allegiance to the survivor: the fight for the throne is merely a combat between the pretenders.

"Would that the human race, which conceives itself to be so wise and perfect, had, under similar circumstances, adopted this principle of action: how much less blood would have been spilt upon this fair earth, whose surface has been so often fertilized by the bodies of human beings, slain in battle!

"The two rivals now fall upon one another with ungovernable fury, whilst the workers stand by as spectators, with their fore legs drawn beneath the body.

"The combatants seize each other with their jaws by the neck, head, and legs, endeavour to confound one another by rapid vibrations of their wings, butt their heads together, grasp each other with their legs, and seek every available opportunity to give effect to their terrible stings. With this view they endeavour to reach the vulnerable portions between the rings of the body, at the neck, or the constricted part that connects the chest and abdomen.

"At length the fatal thrust is given! the dagger penetrates between the rings and enters the vital parts; the pierced combatant shrinks back, staggers, and falls, and, after one or two convulsive throbs, she closes her eyes for ever!

"With ineffable pride the conqueror approaches the corpse, and treats it with triumphant scorn, forgetting, indeed, that it is her sister that is stretched lifeless before her, slain by her own accursed weapon. She spurns it once or twice with her feet, to satisfy herself that life is extinct, and then turns away to receive the homage of her subjects*."

Thus, according to Vogt, do the Bees decide their differences, not by wholesale warfare as with us, but by single combat. Not wishing, however, to interrupt his interesting narrative by interpolating any of our own remarks, we have deferred until now making the inquiry about those Bee-battles that take place in mid-air, *where honey is concerned,* and on which occasions the ground below is literally covered with the bodies of the combatants. How about *those,* M.

* Translated from 'Untersuchungen in den Thierstaaten.'

Vogt? Bees fight for honey, reader, as man fights for money, whatever M. Vogt may say to the contrary!

Although we have shown that the queen is capable, whilst in her virgin state, of depositing eggs that will produce drones, yet this is contrary to the laws even of Bee-life; and the union of the sexes takes place a few days after the appearance of the young queen, one impregnation being sufficient to last her whole life. Indeed, the fertilized queen not only produces and deposits her thousands and tens of thousands of fertile eggs during one season, but, as we have already stated, she is ready on the return of spring to recommence, with full activity, her functions as mother of the hive.

About the time of pairing, the drones, who usually remain hidden in the inmost recesses of the hive, are tempted by the fine weather to leave it and enjoy the genial atmosphere. Presently the queen makes her appearance, and, accompanied by a considerable number of drones, her suitors, departs upon what is termed by apiarists her wedding flight; for you must know, reader, that Bee-marriages are the very reverse of matrimony amongst ourselves. With us marriages are said to be conceived in heaven, and consummated on earth; whereas, in the Bee-world, they are in all likelihood conceived in the hive, and, at any rate, it is now an established fact that they are consummated high up in the heavens*.

* See the summary of opinions on this subject in Siebold's 'Parthenogenesis,' p. 51.

On her return from her wedding-flight, the queen is received by her faithful subjects with every demonstration of joy, and shortly afterwards she commences the deposition of eggs, first (as before remarked) of workers, then drones, and lastly of queens; and, about the beginning of autumn, if the hive be well managed, her fruitful labours give rise to another swarm.

But by far the most wonderful circumstance in connexion with the natural history of the Bee has still to be noticed, and that is the *artificial production of a Queen-bee from a Worker-grub,* should the hive by any mishap be left without a ruler.

To the uninitiated, this phenomenon would appear nothing short of a miracle, for it not only seems to necessitate highly developed reasoning faculties in the insect, but would denote that it possesses a much greater influence in the direction and modification of the laws of nature than do we ourselves.

True it is that we can engraft one species of plant upon another and produce a hybrid, or that we can hatch an egg by artificial incubation; but is there anything in our power over nature that will enable us to obtain a result at all approaching that of the conversion of a Worker-larva into a Queen-bee, as performed by these insects?

Although the operation will always remain a very wonderful one, especially as regards the instinct that guides the Bee in its performance, yet, when it is considered in connexion with the ascertained phenomena in the development of the insect, it will lose

some of its mystery, but, at the same time, will acquire additional interest; for, let us here remark, that, however marvellous some of the operations of Nature may appear to those who are unacquainted with her laws, her attractive features are considerably enhanced when they come to be more fully understood and appreciated.

As before observed, the chief differences between the conditions necessary for the rearing of a queen and a worker are, that in the former the egg is deposited in a *large* oval *vertical* cell, and the insect is fed *during the whole of its larval existence* upon royal paste, a food elaborated by the Bees in their digestive organs; whilst the *worker* is reared in the ordinary horizontal hexagonal cell, and after a certain number of days (according to most authors, on the *third* day after its birth), its food is changed, and it is nourished with a mixture of honey and pollen. The result of this modified treatment in the worker is, that its female reproductive organs, ovaries, &c., are but imperfectly developed; and, as a rule, it is rendered incapable of oviposition*.

Now if, instead of feeding these worker-larvæ only *three days* upon royal paste, they were nourished on this species of food during the *whole* of their larvahood, and if the other conditions as to dimensions

* Whether it is, however, that the workers bred in the vicinity of a royal cell sometimes receive royal food in mistake, or from whatever other cause, it is certain that they occasionally oviposit, but in all cases unfertilized eggs, from which drones only proceed.

and position of the cell were complied with, precisely the same as in the case of the queen, it is quite clear that the worker-larva (which we know to proceed from an egg similarly fertilized to that of a queen) would in due time become metamorphosed, not into a *worker*-bee, but into a *queen*, with fully developed organs of reproduction.

Whether this is known to the Bees, or only to their Creator, we are unable to say; but certain it is, that when deprived of their queen, they at once proceed to a cell containing a worker-egg not yet hatched, or, wonderful to relate, *a larva not more than three days old* (the time, you must remember, when, under ordinary circumstances, its food would be changed!), and they at once alter the conditions of its early existence, so as to convert it into a queen.

They enlarge the worker-cell by the destruction of those surrounding, slaughter the inmates without mercy, and, by the union of the horizontal ones that have been destroyed, form a single *vertical* cradle; they then continue to feed the young larva upon royal paste during the whole of the first period of her life, and treat her in every respect as the future heiress to the throne, into which she in due time becomes metamorphosed.

With the account of this phenomenon, which displays more strikingly than any yet alluded to the omnipotence of the Creator in the adaptation of means to ends, we must now draw this brief narrative of Bee-life to a close. But, before concluding,

let us direct your attention to a few of those features in the natural history of the insect, that, notwithstanding all that has been written on the subject, are still deserving of further investigation. First in regard to the Bee's anatomy. Although it is conjectured that the compound eyes serve to convey to the brain images of *near*, and the simple ones, of *distant* objects, yet this is by no means certain; and any bee-keeper contributing such data as would enable naturalists to decide the question would render a great service to science, inasmuch as that which relates to the Bee in this respect refers also to the other insect races. The same remark applies also to the organs upon the antennæ and wings, as to whether they are organs of hearing or of smell; but this is a more difficult problem, and can be solved only by those who are thoroughly conversant with comparative anatomy, as well as with the habits of the insect.

A very interesting field of inquiry is open in connexion with the reproductive organs of the Worker Bee; namely, as to whether the faculty of depositing drone-eggs, occasionally possessed by them, is the result of their receiving the royal food after the prescribed period, as stated by some authors, or whether, as others affirm, it is a wise provision of Nature to facilitate the peopling of a hive that has been deprived of its queen*.

With respect to the formation of the cells and the

* A friend of Dr. Hicks has a hive that remained many weeks without a queen, and yet the work progressed as usual.

inquiry regarding their normal shape, there now exists an animated controversy, and all observers who have time and opportunity should direct their attention to this strange phase in insect architecture.

The most interesting subject for the consideration of naturalists and physiologists, however, is that of Parthenogenesis, and the queen's power of fertilizing or leaving her eggs unfertilized, so as to produce either workers or drones; and when we recollect that it has but recently occupied the attention of Siebold in Germany, and Owen and others in England, and that the observations of any intelligent bee-keeper may serve to throw additional light upon the subject, we hope this will be sufficient to enlist fresh volunteers in the service, who will aid to elucidate this wonderful phenomenon, which is so strikingly illustrative of the wisdom and resources of the Creator in directing the operations of animated nature.

CHAPTER VII.

VARIOUS DEFINITIONS OF INSTINCT.—ADDISON'S OPINION; DR. DARWIN'S.—THE THEORY OF SENSATION.—SPENCE'S SUMMARY.—DR. CARPENTER'S VIEWS OF INSTINCT AND ITS LIMITS.—ARCHBISHOP TILLOTSON'S EXPOSITION OF THE INSTINCTIVE MORAL PROPENSITIES OF MAN.—COMPARISON OF THESE VIEWS; ANALYSIS OF AN INSTINCTIVE ACTION, ILLUSTRATED BY THE MODE IN WHICH A FLESH-FLY OVIPOSITS; SUMMARY AND DEFINITION OF INSTINCT.—COMPLICATED ACTS OF INSECTS; HOW THEY MAY BE EXPLAINED.—DIFFICULTY OF DISTINGUISHING BETWEEN INSTINCT AND REASON.—STORY OF THE GOLD-WASP AND MASON-BEE, AND COMMENTS UPON THE ACT PERFORMED BY THE BEE.—IS THERE A DEFINITE BOUNDARY-LINE BETWEEN INSTINCT AND REASON?—NECESSITY FOR THE STUDY OF COMPARATIVE PSYCHOLOGY, OR THE SCIENCE OF MIND IN ANIMALS.

To write a treatise upon the Bee without referring to the subject of instinct, would be like publishing a book upon geology, and ignoring the existence of fossil remains of animals, or one on geography, in which the earth was described as though it were not peopled.

It is therefore our intention, or at least our wish, to treat this part of the subject in the same homely and unpretending manner as we have dealt with the physical question, and to consider it from a practical point of view, in its bearings upon our own nature (for the investigation of instinct necessarily connects

itself with that of reason), as well as upon that of the humble creatures whose parts and life-history we have endeavoured to delineate.

As the question of instinct has occupied the attention of many of the most eminent thinkers of all ages, we shall commence by selecting and comparing, in as unprejudiced a manner as possible, a few of the definitions that have at different times been applied to it, that the result may serve to guide us in our own observations.

And, first, let us turn to the pages of one of our valuable companions in these inquiries, "Kirby and Spence"; for we shall there find, conveniently stated for our purposes, the opinions of several eminent thinkers, and not the least important amongst them, that of one of the authors of the work in question.

Mr. Spence, who has perhaps considered as carefully as any man the habits of those creatures in whom the psychical quality known as "instinct" is the most highly developed, glances cursorily at the various modes by which it has been defined, refuting each theory that appears to him incorrect as he proceeds, and summing up with his own ideas on the subject*.

We shall now state those opinions with which Mr. Spence *disagrees*, adding his objections to them, as well as his view of the question; but, before endea-

* Since these pages were written, Mr. Spence has departed this life, leaving behind him a name that will be handed down to posterity.

vouring to explain our own, we shall have to refer to the opinions of more recent as well as of previous writers.

Amongst the definitions of instinct mentioned by Mr. Spence, we find the following:—

1st. That of Addison, who, with some others, believes "that instinct is an immediate and constant impulse of the Deity." The objection raised to this theory is, that "animals in their instincts are sometimes at fault, and commit mistakes, which in the above case could not happen."

2nd. Dr. Darwin, whose opinion is founded upon the views of Pythagoras, Plato, and others, believes that "instinct in animals is the same as reason in man, and that all the actions of animals, however complicated, are, like those of the human race, the result of observation, invention, and experience." This theory Mr. Spence refutes, by showing that as soon as the Bee has emerged from the pupa-case, she at once betakes herself to the collecting of honey or the fabrication of a cell, "which operation she performs as adroitly as the most hoary inhabitant of the hive," and this he presumes would denote in the Bee the absence of those reasoning powers which can only result with time.

At the same time we must add that, although Mr. Spence refuses thus to confound instinct and reason, he does not deny, but attributes a certain amount of the latter quality even to some of the insect races.

3rd. The theory of "sensation," in which instinct is represented as "a predisposition to certain actions,

where certain sensations exist," is passed over very lightly by this authority; and he shows that, although some of the actions of insects are attributable to the effect of appetites, there are others that can certainly not be thus accounted for.

And then, having combated these various theories or methods by which instinct is defined, and rejected others as absurd and unworthy of consideration, Mr. Spence sums up his observations by characterizing this quality in the lower animals as "those unknown faculties implanted in their constitution by the Creator, by which, independent of instruction, observation, or experience, and without a knowledge of the end in view, they are impelled to the performance of certain actions tending to the well-being of the individual, and the preservation of the species."

Having thus endeavoured to cull from the valuable work in question the four definitions of instinct most at variance with each other, we will now turn to the pages of another able authority, namely Dr. Carpenter, in whose treatise on Comparative Physiology we find it stated as his opinion, that the instinctive actions of animals are "performed (as it would appear) in immediate respondence to certain sensations without any *intentional* adaptation of means to ends on the part of the individual*."

His view of instinct appears to be, that it is a propensity or "propensities called into action by sensations," and accords, therefore, to some extent with

* 'Comparative Physiology,' 4th edit. p. 693.

the theory treated so lightly by Mr. Spence, which defines instinct as "a predisposition to certain actions where certain sensations exist."

And Dr. Carpenter, whose acquaintance with the whole kingdom of organic life gives to his views of animal nature an additional claim upon our earnest consideration, endeavours also to ascribe some kind of limits to instinct; and in his summary of the various phases of animal life he attributes this quality more especially to those races of animals included in the *invertebrate* series, commencing with the higher *Radiata* (*e. g.* the Star-fish), and ending with the Hymenopterous group of insects, whereof we know our little Hive-Bee to be a prominent member: in this group the quality of instinct attains, according to his views, the highest development.

In the creatures, on the other hand, that rank *higher* and *lower* in the scale than those just referred to, he traces a gradual disappearance of instinct, which, in the lower, is supplanted by "*contractility*," or the mere mechanical action accompanying organic life, and in the higher by those psychical or mental faculties known as *reason* and *intelligence**. To these views we shall refer again hereafter. But, reader, although these naturalists and physiologists thus circumscribe the character and operations of instinct, there have been metaphysicians in all ages who were disposed to accord a wider range and significance to the term; and, as a typical illustration of the opinions enter-

* 'Comparative Physiology,' 4th edit. p. 704.

tained by such men, we shall quote that of John Tillotson, Archbishop of Canterbury, who died towards the close of the 17th century, and shall leave you for the present to judge how far it recommends itself to your approval, without adding any criticism of our own.

"God hath discovered our duties to us," he says, "by a kind of natural instinct, by which I mean a secret impression upon the minds of men, whereby they are naturally carried to approve some things as good and fit, and to dislike other things as having a native evil and deformity in them; and this I call a *natural instinct*, because it does not seem to proceed so much from the exercise of our reason, as from a natural propension and inclination, *like those instincts which are in brute creatures, of natural affection and care toward their young ones.* And that these inclinations are precedent to all reason and discourse about them evidently appears by this, that they do put forth themselves every whit as vigorously in young persons as in those of riper reason; in the rude and ignorant sort of people as in those who are more polished or refined. For we see plainly that the young and ignorant have as strong impressions of piety and devotion, as true a sense of gratitude, and justice, and pity, as the wiser and more knowing part of mankind:—a plain indication that the reason of mankind is prevented" (that is to say, anticipated) "by a kind of *natural instinct* and anticipation concerning the good or evil, the comeliness or deformity

of these things. And though this do not equally extend to all instances of our duty, yet as to the great lines and essential parts of it, mankind hardly need to consult any other oracle than the mere propensions and inclinations of their nature; as, whether we ought to reverence the Divine Nature, to be grateful to those who have conferred benefits upon us, to speak the truth, to be faithful to our promise, to restore that which is committed to us in trust, to pity and relieve those that are in misery, and in all things to do to others as we would have them do to us."

You will no doubt be puzzled when you come to consider these different views and theories, all propounded by men of high intellect, to arrive at a clear conception of the psychical or mental quality of which they treat; but from this maze of ideas, all of which appear to possess some element of truth, we shall now endeavour to extract something like a definite notion of what instinct really is, bearing in mind that we are not dealing with an object that we can touch, handle, and measure, but with an abstract metaphysical question, which will probably ever remain more or less a mystery to the human understanding.

For this purpose, let us first state the various views of instinct as definite inquiries, passing over, for the present, that of Tillotson.

1. Is instinct in animals the same as reason in man?

2. Is it an immediate and constant impulse of the Deity?

3. Is it a faculty by which animals are blindly impelled to the performance of certain acts necessary for their welfare?

4. Does it consist of propensities called into action by sensations? (or, what amounts to the same thing, is it the result of certain sensations that give rise to certain acts?)

Before proceeding any further, we must dispose of the first theory by saying that, as we shall endeavour to show the marked distinction between the reason of man and that quality in the animal nature known as "instinct," we cannot of course consider them identical.

And now let us for a moment analyze an instinctive action, and inquire how far it illustrates any of the three remaining theories.

A Flesh-fly deposits its eggs upon putrid substances, in order that the grubs that proceed from them may find nutriment upon such substances; and we have every reason to believe that it does this quite unconscious of the end to be accomplished; for some other insects *invariably* (and the Fly sometimes) complete this operation and die before the egg is hatched. The insect can therefore know nothing of the object to be attained by the performance of this act.

Well, in the first place, an egg comes to maturity in the body of the Fly, and, creating certain sensations in the insect, it *impels* it to deposit the egg. This is a direct act of *Nature* (for we shall not stay to inquire whether it is "Nature" or "Nature's God" that gives

the impulse). Now, does the fly at once deposit the egg? No; it appears first to seek a substance suitable for the deposition; and when, by *the aid of its smell*, it finds this, it proceeds to deposit the egg upon it. But now comes a difficulty. *Does* the insect *seek* the particular substance, or is it *attracted* by that substance? for this appears to constitute the difference between the theory, that instinct is an innate faculty ("a faculty implanted") which *impels* the creature to the act, and that which designates it a latent propensity called into operation by sensation.

We have shown that the mere desire to deposit the egg *somewhere* is a natural impulse, *the result of sensation*; but, proceeding now to examine the mode in which that desire is fulfilled, and judging by many analogous examples, we should say that it is not the result of any operation upon the senses from *without*, so much as an impulse from within; that the creature, in fact, *seeks* the substance on which the egg must be deposited. This *mode* of fulfilling the natural want we call the instinctive act, and the impulse to seek the *proper substance* is the "*instinct*" implanted in the creature, by which, "independent of instruction, observation, and experience, and without a knowledge of the end in view," it is induced or impelled to perform that act which "tends to the preservation of the species." Of course, in the case of the Fly it is very difficult to prove that the insect actually *seeks* the substance upon which to deposit the egg, rather than that it is thereby *attracted*; for it may occur to you that

this greedy little plague is frequently *drawn* into our parlours by the sweets of our domestic establishments; but, looking at one or two of the analogous examples in other creatures to which we have just referred, we find the principle established beyond a doubt. The Bee, for instance, rises up in a vertical line in the air before it can ascertain in which direction to fly in *search* of flowers, and, *guided* by the sense of sight, it then flies off in the right direction; again, the dog *seeks* his master's "trail," and, directed by the sense of smell, traces its owner.

But, on the other hand, it must not be supposed that we entirely disagree with the second theory, that instincts are called into operation by certain sensations, and no doubt *practice* or use renders the senses acute, and often animates the latent instinct, without any impulse from within. This state of things is illustrated by the humorous saying often applied to greedy children, that "when geese see water they are thirsty;" and that the sense has such great influence in the direction of the acts of the insect as almost to make it appear the constant exciting cause, is proved by the Flesh-fly depositing her eggs on the flowers of *Stapelia hirsuta*, the smell of which resembles carrion; or the common House-fly placing hers on snuff which is similar in odour to dung; neither substance, however (the flower nor the snuff), being suitable for the nourishment of the young brood.

We can therefore agree with the first theory, that

what is termed "instinct" is an immediate impulse of the Deity, only so far as regards the natural want—the exciting cause,—and must refuse to confound that natural want with its instinctive fulfilment. The quality of *instinct* we would endeavour to define as the *psychical property with which certain creatures are endowed, that prompts them to perform certain acts under the guidance of their senses, such acts tending to the well-being of the individual, or maintenance of the species.* Instinctive actions are performed without the aid of education or experience, and probably, to a great extent, without a knowledge of the end to be attained.

This definition we have so far compiled from the various theories that have come under our notice; now let us continue the inquiry for ourselves. You may be disposed to ask—how do we account for those numerous operations in the insect races with which the senses have no connexion whatever; for instance, what sense can in any way influence the Ant-lion (*Myrmeleo*) when it digs a pit into which its victims may fall?—or the Spider in the construction of its web?

This is a very difficult part of the subject, but the most rational solution that we can suggest is, that along with certain organs and instruments, the creatures have been endowed with the instinctive or intuitive knowledge how to use them; and it is most probable that even in the employment of these they are guided by the sense, or appetite*. Many creatures,

* Judging by the acts of the lowest of animals, in this re-

for instance, resort to certain devices for the capture of prey only when they are compelled to do so by the demands of hunger, and allow it to pass unmolested when no such craving is felt.

The higher we mount in the animal scale, the more complicated such acts become, until at length they merge into those of true reason; and it is sometimes beyond the power of man, in the present state of his knowledge, to decide whether certain actions in the lower animals are purely instinctive, that is to say, performed without the aid of an intelligent will, or whether they are the result of the higher reasoning faculties.

Let us quote, from the pages of Vogt, an interesting illustration of such a mysterious semi-rational act in one of the Hymenopterous insects *.

"The Gold Wasp (*Hedychrum regium*) deposits her eggs in the nests of the ordinary Mason-Bee (*Osmia muraria*), which are often appended to old walls, at a considerable height above the ground, and are provisioned by the builder with honey and pollen. This provender, collected by the Mason-Bee for the nourishment of her brood, is consumed by the larvæ of the Gold Wasp, if the latter succeed in introducing her ova into the nest. One of these, having discovered such a nest, was just in the act of inserting her body for the purpose of depositing an egg therein,

gard, we should be disposed to look upon such displays of instinct as the least intelligent of any.—(See p. 138.)

* Translated from 'Zoologische Briefe.'

when the owner of the nest arrived, laden with pollen, and, with the peculiar hum that is emitted by these insects when making an attack, she fell upon the wasp, and seized her with her sharp jaws.

"The wasp instantly rolled herself up, as is the habit of these creatures when attacked. The bee endeavoured in vain to find some vulnerable part that she might penetrate with her sting, and, her efforts in this direction proving fruitless, she at length bit off the wings of the Gold Wasp at the roots, and then dropped her to the earth. After this she returned to her nest, evidently in great anxiety, in search of an usurper's egg, and, finding none, she flew off to seek a fresh store of food.

"The Mason-Bee must doubtless have been satisfied" (Vogt is speaking, it must be remembered) "that, by removing the wings of the wasp, she had prevented her from repeating her visit to the nest; but here she was mistaken in her reckoning. The prostrate wasp unrolled itself as soon as the bee had departed, crept in a direct line back to the nest, and deposited her egg therein."

Now let us for a moment inquire whether the bee was acting under an instinctive impulse when she bit off the wings of the wasp, or whether, in so doing, she was guided by anything approaching to reason. Vogt, who is a great advocate for the existence of reason in the insect races, or rather, who is disposed to endow them with a great amount of intelligence, quotes this anecdote (as we have seen by his brief

comment on the bee's *motive* in biting off the wings) as an example of the reasoning faculty; and really, upon the face of it, it bears every indication of a rational act, with all the weakness of imperfect reasoning powers. *Apparently* the Bee bites off the wings, these organs coming under its immediate notice, which it knows would convey its enemy back to the nest, if they were left unimpaired; but she forgets that it can reach the same goal by the aid of its legs alone, just (to borrow the idea of a friend to whom we narrated this anecdote) as an unskilful general seizes one position that he considers essential to obtain a victory or secure a defence, whilst he overlooks some other post by which the enemy penetrates and spreads havoc in his ranks. But a little further reflection overthrows all these ingenious speculations, and we are compelled to ask ourselves, did not the Bee, under the impulse of anger, and from the instinct implanted in it for the preservation of its offspring, in attempting to destroy its enemy, just bite off that portion of its body which was vulnerable and approachable, and, having thus vented its rage, fly off, as its instinct prompted, to satisfy itself of the security of its offspring? We shall not pretend to decide under which class of actions this one may be said to rank, but certainly we should be equally reluctant to accept the dictum of another on the subject.

But this difficulty in defining the exact limits that separate instinct from reason need not deter us from

endeavouring to trace such distinguishing features in each as will enable us to form some conception of its general character. Besides, who can say that there are definable boundaries to either quality?

There are creatures in existence, whereof you may take one and show it to an experienced naturalist, who will feel, handle, and dissect it, follow its life-history from the incubation to the death, and, after careful and unbiassed consideration, will tell you that it is a fish. Give the same creature to another equally talented zoologist, and he will, after the same toilsome investigation and scrutiny, declare it to be a reptile. Is it not possible that, like the travellers and the chameleon, both these men "are right, and both are wrong"?—right in detecting the characteristics of that group in which they respectively rank the living object, wrong in attempting to force upon Nature limits that do not actually exist, and placing the creature in some square or circle in the Animal Kingdom, which they find it necessary to draw with mathematical precision, in order to aid their limited understandings, and facilitate the studies of those whom they desire to instruct?

Well, then, if these difficulties arise in deciphering the true nature of the external and visible forms of animals, how much more perplexing must be the attempt to define the precise character of the various phases of mind with which they are endowed! And again, as in the case just quoted with reference to the classification of animal forms, who has a right

to divide the whole mental nature of those races, including man, into two circumscribed provinces, "instinct" and "reason"?

It is but very recently that physiologists began to detect those true typical features, external and internal, that characterize the various groups of animals; and we believe that, when as much attention shall have been devoted by naturalists to the consideration of the psychical properties of animals as has been brought to bear upon the investigation of their bodily structure, the old boundary that separates instinct from reason will disappear, and they will find numerous avenues through which to pass from one field of mental life to the other. The time is not far distant when a scientific account of the mental attributes of every group (or, if needful, of every genus or species) of animals will be deemed an indispensable adjunct to works on zoology; and, as the class of readers who were formerly satisfied with a superficial description, provided it was an interesting one, of the external forms and characteristics of animals, now require to be enlightened with regard to their anatomy and physiology, so will such as are at present contented with a few anecdotes concerning their habits and mode of life, expect to be minutely informed regarding their inner springs of action, and the relation of these to the visible organs of the living fabric. When we observe how rapidly whole races of animals are disappearing from the surface of the globe, we cannot fail to perceive the importance of such a work, which

should be completed whilst the creatures still follow their natural mode of life, and before they are domesticated or exterminated by the irresistible progress of civilization.

Sufficient information is, however, not yet collected to enable a comparative psychologist to set to work and systematize the various mental phenomena in the Animal Kingdom, nor would this be the place to do so, even if the materials were at hand. As, however, our object in undertaking this work has been to popularize and give an impetus to the study of science, we shall bring before you a few examples of a gradually progressing mind in animals, dwelling as much as we are able upon the mental properties of our little Bee, and you will see with what intense interest the subject is invested, and how that unity which everywhere presents itself in the visible creation may also be distinctly traced in the invisible world.

CHAPTER VIII.

VEGETABLE LIFE.—MOTILE PLANTS.—ABSENCE OF MENTAL PROPERTIES IN THE LOWEST TYPES OF ANIMAL LIFE.—UNITY IN THE PROGRESSIVE DEVELOPMENT OF MIND AND BODY IN THE ANIMAL KINGDOM.—SENSATION THE FIRST INDICATION OF MIND.—PSYCHICAL PROPERTIES OF THE SEA-ANEMONE.—THE ACTINIA AND THE HUMAN INFANT.—"ANIMAL" OR "NATURAL INSTINCT": ITS UNIVERSALITY IN THE ANIMAL KINGDOM.—THE INSECT RACES: THEIR HIGHER PSYCHICAL POWERS; FITNESS OF THESE FOR THE USES OF THEIR VARIOUS ORGANS, MEMBERS, AND ACTIONS.—NECESSITY OF THE HIGHER PSYCHICAL POWERS OF INSECTS.—THE BEE.—ITS EMOTIONS.—EXPERIMENT TO PROVE THE PRESENCE OF ITS FEELING OF ANGER.—DO BEES THINK?—ABSENCE OF EDUCABILITY IN INSTINCT.—"RATIONAL INSTINCT."—"REASON," OR INTELLIGENCE: ITS RELATIONS TO THE CEREBRUM: EDUCABILITY, AND DESIGN OR CONSCIOUS MOTIVE, TWO OF ITS CHARACTERISTICS.—THE TWO CROWS AND THE DOG.—"INSTINCTIVE INTELLIGENCE."—THE DOMESTICATED ANIMALS AND MAN.—NATURE OF THE DOG: ITS MORAL WORTH; ITS SENSE OF DUTY.—TREATMENT OF DOMESTICATED ANIMALS AND CHILDREN.—ATTRIBUTES OF PERFECT ANIMALS COMPARED WITH THOSE OF IMPERFECT MEN.—CHARACTERISTICS OF HUMANITY, THE ANALOGUES OF THE NOBLER TRAITS IN THE HIGHER ANIMALS.—TILLOTSON'S VIEWS OF THE MORAL INSTINCTS OF MAN CONFIRMED BY COMPARATIVE PSYCHOLOGY.—THE DOG AND THE MAN.—MAN AND THE DEITY.—SUMMARY OF THE

MENTAL ATTRIBUTES OF ANIMALS. — RETROSPECT. — ARE THE WORM, THE FLY, AND THE BEE COMMONPLACE AND UNINTERESTING ?—WHICH IS THE MOST INDISPENSABLE ?—THE CARE OF THE ALMIGHTY FOR ALL HIS WORKS.—THE VARIOUS MEANS EMPLOYED BY HIM TO ATTAIN SIMILAR ENDS.—HIS CARE OF US.—THE RELATION OF THE HUMBLE CREATURES TO OURSELVES, AND OUR RELATION TO GOD.—CONCLUSION.

It is a well-known fact, that certain plants are capable of performing movements of a limited kind, that are necessary for their protection or development. To select two very familiar examples: the daisy closes at night and opens in the morning, so that the central whorl of delicate flowers escapes the effects of the night air; the sunflower is always turned towards the solar orb, which it follows in its course, in order to secure its vivifying influence throughout the whole day.

These movements take place whilst the plants remain fixed in the ground; but there are other examples in the vegetable kingdom, where the organisms themselves, which are aquatic, move about in the water with great rapidity, propelled by little hair-like elastic fibres termed "*cilia*," that vibrate rapidly to and fro; and, strange to say, although these plants are thus remarkably endowed with an attribute usually supposed to belong only to the animated tribes, yet they rank amongst the *lowest* types of vegetable life*. So closely do some of these "*protophytes*" resemble

* e. g. *Volvox Globator* (a little green rolling globe, found in ponds in great numbers, especially in summer), *Gonium*, &c. &c.

the lowest known forms of animal life, distinguished as the "*Protozoa*," that many of them are even now bandied about by naturalists from one kingdom to another; and it will probably be a long time (if it should *ever* be) before a clear line of demarcation is drawn between the two realms of animal and vegetable existence.

For our purpose, however, it will suffice to state, that, in all probability, these primitive types of life, whether animal or vegetable, perform their various movements, imbibe nourishment, grow, and reproduce, without any appreciable psychical or mental properties, and that their motions are due alone to the contractility of their tissues. Here, therefore, although we have life, movement, growth, and reproduction, we have no animating power that can with propriety be called "*mind*."

And now, before entering the arena of true animal existence, and endeavouring to trace in outline the progressive stages of mind in the various races of sentient beings, we must repeat a statement made in the first of these treatises on Humble Creatures *, where, in speaking of the principles upon which the modern classification of animals is based, we observed that "each great division of the Animal Kingdom exhibits a progressive development in the organization of the various groups that it contains; and also that, in following the life-history of a *single* individual in each section, a remarkable analogy is apparent be-

* 'Earthworm and Housefly,' p. 27.

tween the various stages of development through which it passes and those existing in the whole class.

So striking is this comparative progress in the organization of classes and individuals, that the *lowest* creatures in any particular section strongly resemble, when in their *perfect* form, the *early* or *embryonic* stage of the *higher* animals in the same section, the latter undergoing various changes of form and structure before they assume their characteristic type."

Thus, to illustrate this proposition, the vermiform, or worm-shaped creatures, which rank *lowest* in the articulate races, resemble, *in their perfectly developed state,* the insects (which are the *highest* of the articulate tribes) in their *larval* or *imperfect* stage of growth.

Any one who has been at all impressed with the unity exhibited in all the natural operations of the Creator, and the intimate connexion existing between matter and mind, will of course expect to find the same phenomena in the psychical or mental as in the physical history of animated nature; and a consideration of the following brief sketch of the mental development of the various races of animals will serve to show that the parallel does exist, and may readily be traced.

Quitting, then, those doubtful forms of which it is difficult to detect the true nature, we soon arrive at a group of creatures possessing an undoubted animal existence. In these, the inner mainsprings of action are linked with the outer world by a chain of *sensations,* and the exciting cause of their movements

is wholly dependent upon the appetites or natural wants*.

Let us quote a familiar example of this blind, unconscious, mechanical instinct, illustrative of the lowest psychical phase of which we can well form a conception.

You have doubtless seen the common Sea-anemone or Actinia, adhering to the rocks at low-water. If you go and watch this creature when it is covered by the tide, or (if that be impracticable) in the aquarium of a friend, you will perceive it from time to time extend its tentacles to their full extent in search of food. Presently a little shrimp or other living creature comes in contact with these tentacles, and at once it is seized and conveyed into the capacious stomach; indeed the creature itself is little else than a stomach endowed with the capability of feeding itself, and possessing limited powers of locomotion. As soon as it has obtained a sufficient amount of nourishment, and has satisfied the cravings of appetite, it shrinks up into a jelly-like shapeless mass, resembling an excrescence growing upon the rocks; and any living creature, however tempting a morsel it might otherwise be, may then approach or impinge upon it without danger of falling a prey to its voracity.

* If the term "instinct" were limited to such a mental quality as is here described, then the theory of "sensation" (see page 119) would perhaps constitute the most appropriate definition that could be applied.

These, and similar actions necessary for the development and growth of the individual, are prompted by hunger, or some other natural want; and their analogues may be found in *every* living creature, beginning with these humble forms of life and ending with man. And mark, reader, how strikingly the principle is here illustrated that we quoted with reference to the comparative physical and mental development of animals. The instinct that prompts the Actinia, one of the lowest forms of animal life, to stretch out its tentacles in search of prey *in the same mechanical manner throughout its whole life,* and which is therefore one of the mental characteristics of *its perfect* nature, this instinct, we say, is repeated, with but little variation, in the human infant during the *earliest* stage of its existence, when it turns to the mother's breast for food as mechanically as the Polype extends its feelers in the water with the same object,—namely, that of obtaining a supply of nourishment.

As before remarked, we are not going to attempt a formal classification of the mental attributes of animals; but the most appropriate term that occurs to us, as a designation of this class of psychical properties, is "natural or animal instinct," by reason of its immediate relation to all the most urgent requirements of the animal nature.

But as we travel upwards in the animal scale, and look around us amongst the insect races, we cannot fail to observe in these a class of actions prompted by

mental impulses, and resulting from psychical powers that are as distinct in their nature from those just described as are the active and highly organised creatures themselves from the Anemone, growing, as it were, upon the rock. And is this not perfectly natural, and in accordance with the progressive development exhibited in the structure of the animals? In the radiate types we have a set of tentacles, long or short, thick or thin, hard or soft, but always tentacles, and nothing more. Their office is to seize the food with which they come into contact, and convey it to the stomach, and for this object their simple form is amply sufficient.

But now, turning to the insect tribes, we find in the *Mantis** and others, certain parts of the members of locomotion, &c., transformed into powerful blades or claws, with which they are enabled to capture and despatch their prey. The Spider, again, possesses a set of spinarets wherewith to weave a web for the same purpose, and a combing apparatus upon each foot, to aid it in its operations. The suctorial insects are furnished with probosces, or suction-pumps, and the parasites with lancets, that are used to extract the juices from plants and animals.

* *Mantis religiosa* is an interesting and well-known insect of prey, a native of the South of France, that usually assumes the attitude of prayer (hence its name) whilst watching for passing flies, which it strikes down with its scythe-shaped fore-legs.

Now, as each of these weapons must be wielded in a particular way, is it not quite obvious that the owners must be taught how to employ them? or, in other words, must they not all possess *varying powers of mind*, to enable them to attain the same end by different means? Is it reasonable to suppose that one and the same impulse or psychical endowment, implanted in the Spider and in the Bee, will cause the former to weave its web and wait patiently for the approach of its prey, and the other to fly off to distant meadows or gardens, and there penetrate the nectaries of flowers in search of honey? Would it be wise to assume that both these instincts resemble, in their psychical character, the imperfect faculty whereby the Actinia is prompted to extend and retract its tentacles? Certainly not. Such a theory would be just as absurd as to suppose that the same powers of mind as those which direct the Bee and other insects in the use of their natural implements would suffice to enable man to deal with all subjects in connexion with the arts and sciences.

When we contemplate the mode in which the various insects employ their exquisitely constructed instruments, of widely differing character, we cannot help perceiving that the Creator has endowed each of these His creatures with a circumscribed mental capacity; but, at the same time, one that enables it to perform its complicated operations to the best advantage. Nor must we forget that not only has He centred in *us* all these psychical endowments, placing

us at the same time in a position to *form similar* instruments for our own use, but He has in His mercy crowned us with reasoning faculties, that we may appreciate His goodness, and assist in the fulfilment of His great ends by their wise and judicious employment.

But there are other reasons why the mind of an insect should be differently constituted to that of an Actinia. The latter is fixed upon a rock in the sea; and, though it certainly possesses limited powers of locomotion, yet there it is, always at the mercy of a passing fish or Crustacean; these browse upon it, just as a sheep grazes upon the meadows. But with the insect it is otherwise. The Bee, for example, has been placed in a completely different natural sphere; it builds for itself a dwelling to afford it protection from the weather, fortifies it to exclude enemies, and cements it down firmly that it may not be left at the control of the wind, as the Actinia is tossed about by every passing wave. For this purpose it has to seek certain natural substances, which serve the little architect as bricks and mortar; and these operations necessarily require discrimination, or what in ourselves we term *judgment*; for, as it sometimes happens that the proper materials are not within reach, the Bee is then obliged to employ substitutes, and in so doing it never blindly chooses the less efficient substance when a better one is at hand, but invariably uses "the right thing in the right place."

And, moreover, Bees communicate information to one another, and they also possess *emotion* as well as sensation.

Do you doubt this assertion? Then go to a bee-hive, and lay a small twig, or some other obstacle to the free passage of the inmates, across its entrance. As the labourers pass in and out of the hive, they inspect it carefully, and first you will see one or two Bees crawl over, and examine it with their antennæ; then they enter and inform, probably, the Police-bees inside.

Presently a few more make their appearance from within, and, if you have the courage to stand your ground, two or three detectives will fly about your head, and by their angry hum will give you a hint that it would be advisable for you to remove the stick, or make yourself scarce.

But you may leave the twig a little longer, for the Bees won't attack you at once, unless you show signs of fear; and when you find the number increase about the entrance of the hive, withdraw the stick and go away *to a considerable distance.* You will then see them come forth in masses just as though they were going to swarm, and had you dared to stay you would have been attacked and seriously stung, for daring to disturb the even tenor of their existence.

On one occasion we ventured to stand near the hive a little longer than was discreet whilst trying this experiment, and were actually attacked by some of the Bees, one of which flew against our face

and stung us, with every demonstration of anger. At any other time we could approach the entrance of the same hive with perfect security, protected only by a sprig of wallflower, and we remained near enough to be enabled to watch the ventilating Bees in their operations inside of the hive. This proves clearly that the *anger* of the Bees was excited by the interference with their habitual proceedings; but whether they knew who was the disturber of their peace, or simply attacked us as the nearest living object, is a question that must be solved along with the one already mentioned in connexion with the anecdote of the Bee and the Wasp*. That their knowledge or psychical power, *under such exceptional circumstances,* cannot be very great, is certain from the fact, that, although when about to swarm they send out scouts to a considerable distance, and in their search for honey they will fly several miles from their habitation, yet they will not attack a person who has deranged the economy of their hive as narrated above, if he but remove to the distance of twenty or thirty yards.

And, furthermore, although many of the complicated actions of the Bee and other insects bear evidences of discrimination and emotion, and are

* One may form some conception of the mode in which the Bees apprehend the relation between the stick across the entrance of the hive and the living object standing by, if he secretly abstract some favourite toy with which a very young child is playing, and watch the effect in its actions and countenance.

of a decidedly higher character than those simple movements and operations performed by the creatures placed lower in the animal scale, and though it has hitherto been impossible to distinguish many of the former from truly rational acts, yet we do not consider the whole mental nature of these animated beings entitled to a higher designation than that of instinct. Notwithstanding that it foreshadows those psychical powers and faculties that become developed in the reasoning creatures, yet it wants at least one clearly-defined quality which is now employed, as it appears to us, with great propriety, to stamp the nature of true reason; and that is *educability*.

Insects never improve in their mode of proceeding, nor excel one another in the ability with which they perform their labours; there never was a Bee wiser than another Bee, nor a generation of Bees that effected improvements in the economy of the hive; and if we were *able* to suggest to the creatures an improved *modus operandi*, it is questionable whether any amount of teaching would have a perceptible effect upon them.

A careful consideration of the nature and phenomena of this *higher* phase of instinct has suggested to us the designation of "*rational instinct*" as an appropriate one to denote its character; for as soon as the various creatures that are thus endowed attain the imago, or perfect state, they at once *instinctively* or intuitively perceive the relation between the various organs wherewith they are furnished

and the materials on which they are intended to operate, and, without any experience or tuition, proceed at once to employ both organs and materials in a perfectly rational manner*.

And now, having drawn attention to two essentially different phases of instinct, the lower one purely mechanical and ministering to the immediate natural wants of the individual, and the higher involving truly rational acts (such as in ourselves necessitate previous tuition and experience) that enable the animal to provide not only for its own wants, but for the necessities and welfare of its congeners; having selected these from amongst many progressive phases of instinct, let us now pass that boundary whereon so many naturalists have wandered life-long, and, entering the province of reason, endeavour to form some idea, however imperfect, of its distinguishing attributes.

We believe it to be the acknowledged theory of physiologists in the present day, that the true reasoning faculty is immediately connected with the possession of a *brain*; or, to be more precise, that

* The simile of Rogers (page 13) is perhaps more appropriate than even he imagined; and if we could follow the mental as we can the physical development of the Bee through the various stages of larva, pupa, and imago, we should probably derive from the study a valuable lesson bearing upon our own psychical nature. There can be no doubt, that, in its larval condition, the insect is collecting substance in preparation for its higher existence; and, in a figurative sense, the same remark applies to ourselves.

reason or intelligence is only found in such animals (those being the Vertebrata) as possess a *cerebrum*, that is, the upper portion of the brain, composed of two lobes or imperfect hemispheres. And, furthermore, it is held that the *character* of the cerebrum in the various animal races is also the *measure* of intelligence; for it is found that as this part of the brain increases in *size* (not as compared with the *body* of the animal, but with the remaining portions of the nervous system), and in accordance, too, with the increasing amount of *grey vesicular matter* composing its surface, so does the possessor rank in the scale of intelligent creatures.

But although these physiological distinctions serve as indications of intelligence, yet they will not of themselves teach us the difference between that intelligence and the mental qualities of the invertebrate races, and it is necessary that we should look to the actions of the various creatures before we can hope to form anything like a correct estimate of their psychical nature.

In our concluding remarks concerning instinct, we mentioned that this property is not susceptible of development; that, however complicated the actions resulting from it may be, they are, as a general rule, the same under all circumstances; in fact that a *negative* feature in "instinct" is the absence of *educability*. What we have, therefore, first to seek in *reason* or *intelligence*, as a distinguishing characteristic, is the last-named attribute, and in a greater

or less degree we find it in nearly all the Vertebrata, beginning with the higher reptiles, and ending with the most intelligent human being. This susceptibility of improvement is exhibited in various ways, such as the mode in which the parent teaches its offspring to perform certain acts; or the readiness with which it conforms itself to the habits of man, and casting off its savage propensities, yields to his civilizing influences.

To quote illustrations in proof of the presence of this quality would be quite superfluous, for whoever has watched the habits of the higher animals in a wild state, or has kept any domesticated ones, cannot fail to have witnessed examples of their educability, and reserving this attribute for subsequent consideration, we shall now pass on to another characteristic of intelligence, namely, *design*. By this we mean a distinct consciousness on the part of the creature that it is adapting a means to an end, however humble may be the object to be attained.

That the Fly does not know wherefore it deposits its ova upon certain substances suitable for the nourishment of its offspring, no one will doubt; for, as before stated, it may in all probability be dead before the eggs are hatched; and it is at least very questionable whether even in performing the most complicated instinctive actions, these creatures are conscious of the end to be attained. Reminding you of Vogt's anecdote of the Bee and the Wasp*, in which

* Page 128.

you will recollect that the former bit off the wings of the latter, *either* in order to prevent it from flying to its nest, *or* (as we believe most reflecting naturalists would say) because it was the only part of its enemy that was vulnerable, we will now contrast with this very questionable exhibition of the reasoning faculty, another mentioned by a writer in an illustrated periodical*, in which a bird is the actor.

He narrates an anecdote of two crows that were watching a dog gnawing a bone, of which they were very anxious to obtain possession. The dog, however, kept such a sharp eye upon them that they dared not approach him openly, but one of the crows slipped quietly round to the back of the animal and began to peck at his tail with its beak. No sooner did the dog turn his head to defend himself from this rear attack, than the other crow hopped up, and, seizing the coveted bone, flew off with it. Now, here we have not only an evidence of design, but a cunning, premeditated plot; and we say these crows richly deserved their bone for the intelligence they displayed in obtaining possession of it.

In these creatures, therefore, as we see by the foregoing example (which is one in a thousand), there is, combined with a low reasoning power, a considerable amount of cunning; and not only might similar traits be pointed out in the nature of the higher animals, but even in man himself we not unfrequently find a defective or debased intellect accompanied by great

* 'Once a Week.'

craftiness of disposition, and a constant recourse to stratagem. This is another striking example of the unity that is presented by the progressive stages of mental development; and the close resemblance existing between the qualities that characterize the *perfect* types of the *lower* Vertebrata and the attributes of the *imperfect* man, clearly denotes that these psychical properties belong to one and the same province in the realm of mind. This lower phase of reason may with propriety be termed "instinctive reason," or "instinctive intelligence*;" for, although the creatures thus endowed possess a certain degree

* This term has been applied by Coleridge ('Aids to Reflection,' p. 181, Pickering, 1839) to the nature of the Bee and other insects, in consequence of the *power* displayed by them of "adapting the proper means to proximate ends according to varying circumstances;" and his inference is drawn more especially from their devices employed in the construction of their dwellings. This definition of *intelligence* does not, however, appear to us sufficiently clear; unless Coleridge attributed that quality to the Hermit Crab and to numerous other creatures that have the power either to appropriate objects ready formed as dwellings, or to construct them from various materials, according to circumstances, but which rank very low in the animal scale. Availing ourselves of the "aids to reflection" afforded by the latest and most eminent psychologists, we conclude that before such actions as those referred to by Coleridge, *apparently indicative* of intelligence, can be considered to be truly so, it must be shown that the creatures are *conscious* that they are applying the proper means to the proximate ends. The line of demarcation is, however, exceedingly faint and difficult to distinguish, as we have repeatedly declared in the foregoing observations on instinct and reason, and Coleridge's reflections on the subject, beautiful though they be, are unfortunately not calculated to render it more easily definable.

of educability, yet their actions are directed to the support of the individual or community, minister to the animal enjoyments, or provide for the continuance of the species, all of which we know to be the distinctive attributes of instinct; but they exhibit none of those higher moral qualities that we find in the domesticated animals or in man.

The natural educability, however, of the former of the two last-named, and their expanded mental capacities, combined with the influence produced by their contact with man, create an entire change in their psychical nature, and the intelligence of the brute is elevated to such a degree as to render it capable of acquiring not only the habits of its master, and many of his emotions, but even, in a limited degree, some of those divine attributes by which he is distinguished from all other living creatures.

It is a well-known and a true saying that man is the god of the dog; and all those finer emotions of the humble companion of mankind, such as the love that causes him to spring forward to the rescue of a drowning child, the submissive obedience with which he performs his owner's behests, the devotion that prompts him to lick the hand that has chastised him, the grief that chains him to his master's grave, and so overrules his instincts that he will die of hunger rather than quit the spot where his benefactor lies buried; all these manifestations of emotion and intelligence entitle their possessor to a mental rank, very closely approximating that of many a human

being. Indeed, it is well known that amongst barbarous nations the sympathy and affinity existing between man and his domesticated companions amongst the higher animals are so great, that he not only lavishes upon them as much tenderness as upon his blood-relatives, but that his very conception of heaven is allied with the expectation of there meeting his four-footed associates, just as we hope to be reunited hereafter with those departed friends whom we have loved on earth.

Let it, however, be clearly understood, that although we believe the higher vertebrata, and more especially the domesticated animals, to be endowed with a certain amount of reason such as we find in ourselves, and *transmitted through the human race*, yet we would not for an instant encourage the doctrine that their natures are akin to our own; or that man does not possess an infinitely higher degree of intelligence than do these valuable creatures. The attempt thus to raise *their* nature would involve just as grave an error as if we were to delude ourselves with the idea that we are Deity because we have been honoured by our Creator with the possession of some divine attributes.

The dog may be said to stand at the head of the animal races, so far as his psychical properties are concerned, and the high degree of his instinctive *intelligence* bears the same relation to the *lower* phase of that quality, exhibited in the untutored brutes, as does the rational *instinct* of the higher insect races to the animal or natural instinct in the lower inver-

tebrate forms, in which we find the first indications of an independent power of action; *another* instance this of the unity of purpose and regularity of design that characterize the development of mind in the animal kingdom.

But there is in the character of the domesticated animals one moral trait which, above all others, leads us to a comparison of their natures with our own, and that is, the consciousness of having committed a fault or performed a meritorious act; in other words, their *limited* sense of right or wrong.

It is needless to refer to books for exemplifications of the truth of this statement; for who that has kept a favourite dog does not know that the animal is frequently conscious whether its actions deserve reward or punishment? And if we come to compare our *treatment* of these creatures with our method of dealing with our own little ones whilst the instincts still predominate in these, we shall find that unfortunately the same rod is too often applied to both, in order to suppress their mischievous propensities, and to instil a sense of duty and propriety.

The means employed in either case are probably injudicious, and the result of ignorance on the part of the tutor*, but the end is similar in both; in the case of the domesticated animal, to educe that in-

* Witness the modern mode of treating *children* in public schools, as compared with the whipping system of old; and Mr. Rarey's method of training *horses*, in contrast with the use of the whip and spur.

tellect which cannot outstep certain bounds, but which in the human being enables him through his free will and self-educability to develope those moral and spiritual properties that constitute the perfect man.

Here we again find an example of the close resemblance between the *perfect* nature of the lower creature and the *imperfectly* developed stage in the higher, and if we were to investigate those baser qualities which, either in the child or in the adult, are not brought under the controlling influence of reason, such as cunning, avarice, deceit, treachery, &c., we should find that they form the characteristic feature in the completely developed nature of one or other of the untutored brutes; thus further illustrating the accuracy of the foregoing proposition.

But does this unity terminate here? Is the only bond that connects man with the universal realm of mind to be found in his vices and imperfections? Are there no traits discernible in his character that, whilst they show him to possess an animal nature, prove also that he is linked with a Higher as well as with the lower intelligences?

Some men might dread to push this inquiry further, lest they should shock their preconceived ideas, inherited or otherwise, concerning their own nature; but if the subject be approached with due reverence and diffidence, no such result need be anticipated.

There is nothing unworthy in the character of the lower animals; and it is only when we find moral, reasoning man, who was created for a higher end

than they, governed by brutish passions, it is then only that these qualities become detestable; and if we calmly consider the nobler traits in the disposition of these creatures, we shall find that their analogues in ourselves are the very features that constitute our humanity, and the tie that binds us with the Creator.

When Archbishop Tillotson called the impressions of right and wrong, and the inclination to reverence the Divine nature existing in the minds of men, *instinctive*, and when he compared them with the instincts of the brute creatures*, he meant to point out that these are the *typical qualities* that characterize *his* nature; just as the lower animals are distinguished by their various instinctive attributes; and a comparison of their nature with our own shows that his assertion was not merely a figure of speech, but that the principle which he enunciated forms the crowning feature in the comparative history of mind. In the dog, for example, the nobler moral traits are not, strictly speaking, natural, but they are the connecting links brought into existence by his association with ourselves.

We educate him for our purposes. He is trained, along with the other domesticated animals, to be of service to man, and is the reflex of his master; if the owner be of a kind and gentle disposition, so is the dog; if the former be wild and unbridled in his passions, so also is the latter; and the more the dog

* Page 122.

associates with man the more fully does he partake of his nature.

These moral features, then, that are imperfectly and artificially developed in the lower animals,—this restricted sense of right and wrong, this veneration for the higher nature of man,—find their analogies in our own character; they are the natural instincts of the human being, and in him they assume the form of moral responsibility and veneration for the Divine nature.

And if the dog becomes by education and association with man the reflex of *its* master, do not we in like manner resemble Him the nearer we approach Him, and the more intimate we endeavour to make our relations with Him by communion and imitation? Just as our humble companions draw their moral excellence from us, do not we derive strength, wisdom, love, and hope from the Source of all these qualities? and does not the last-named attribute of our nature, hope, spur us on to the fulfilment of all that is high and noble*? Do not we learn through this medium, that, just as the humble associates of our earthly existence become more useful to us in proportion as they are trained for *their* work, we, too, most perfectly fulfil the objects of our existence, the more we exercise our moral and intellectual faculties; and that the better we train and school ourselves, the

* Free-will and the inventive capacity are also striking attributes that form a connecting link between man and his Maker.

more completely shall we be fitted to become the companions and the co-workers of a higher Intelligence hereafter?

The consideration of the psychical or mental natures of the various races of animated beings leads us therefore to the following conclusions:—

First, that in the invertebrate animals the mental properties assume the character of animating influences that prompt the creature to perform certain acts, of a more or less complicated kind, intended for the well-being of the individual or continuation of the species; and that the senses alone operate as the guiding or controlling power. These mental powers or properties, which are, as a general rule, not susceptible of improvement or development in the perfectly formed creature (that is to say, after the creature has attained its perfect stage), are popularly known as *instincts*.

Secondly, that the Vertebrata, or those creatures that are characterized by the possession of a true brain, are endowed with similar animating properties, guided in like manner by the sense, and having the same object and tendency as the so-called instincts of the invertebrates; but, superadded to these, many of them possess ethical powers and qualities that in their turn control and govern these instincts, and which are susceptible of a greater or less degree of development or educability. This educable property in the case of the higher animals (where it is but limited) is the result of association with one another

or with man, and in ourselves it is quickened by the observation of Nature, the association with man, and by communion with the Infinite. These higher qualities have been variously designated as Reason, Intelligence, and Understanding.

Thirdly, that in the present imperfect state of our knowledge it is impossible to define with exactitude in which groups or genera of animals the higher or intelligent nature is first found in combination with the lower or mechanical; and many of the acts of the higher invertebrates are capable of being attributed either to instinctive impulses or to imperfect reflection.

Fourthly. The most important result of our brief review, and the one likely to be of the most service in future inquiries, is that the same uniformity and regularity of purpose is traceable in the psychical or mental as in the physical or bodily structure of the animated tribes; the perfect nature of the lower types being repeated in the imperfectly developed phases of the higher, and nobler qualities being added in each succeeding stage of progress; so that the beautiful web of life appears to have been woven with a constant accumulation of varying threads, and all taken up and held by the unseen hand of the Author and Supporter of existence.

Having now brought our investigations to a close, there remains to us the task of reflecting, in the exercise of that reason or intelligence which we have

found to be the characteristic attribute of our race, upon the moral and intellectual benefits to be derived from the contemplation of such creatures as this Earth-worm, Fly, and Honey-Bee, to whose nature we have devoted a few descriptive pages, as well as from the review of the mental attributes of animals, including those of our own race, which has necessarily formed a portion of our subject.

If you permit your thoughts to travel back to the commencement of the first of these little treatises, you will recollect that the object with which we set out was, if possible, to show how the humblest and most commonplace of Nature's forms are deserving of our careful attention, not only from their intrinsic value as works of the Creator, but as affording useful lessons in the education of our minds. That we have not been able fully to accomplish this object through the printed pages of a book may be easily understood; but the imperfection of the artificial means employed must by no means be regarded as a proof that the consideration of the living forms themselves would be alike insufficient for the attainment of the desired end.

Not only will the careful investigation of those creatures be far more agreeable and more conducive to the formation of a well-ordered mind than the mere perusal of a descriptive text-book, but it cannot fail to lead to discoveries on the part of the student that will entitle him to rank amongst the pioneers of knowledge. We shall, however, proceed to employ the means at our disposal, and to ascertain what results

we have been able thus far to obtain from our popular inquiries.

First, then, we trust that we have succeeded in showing beyond a doubt that those creatures which many persons are in the habit of regarding as commonplace, or even contemptible, are found, on nearer examination, to be far more interesting than the first glance would lead us to imagine, and that the consideration of their various parts serves to teach us, in a simple and efficient manner, upon what principles the organization of the whole animal fabric is based. The ease with which we can penetrate their external integument or envelope for the purpose of examining their vital organs, or can even contemplate the functional operations of these whilst the creatures are alive, without the infliction of pain or injury*, renders them peculiarly suitable as objects of study for the uninitiated in the mysteries of science.

We have seen also that their abundance is a great advantage in the sense just referred to; for those who have not the time, inclination, or opportunity to enter a dissecting-room, may almost at any time secure a Worm, a Fly, or a Bee, and submit it to microscopical investigation. The very universality, therefore, that has rendered them so commonplace, constitutes in the eyes of the naturalist their chief value as objects of study and investigation.

But have we found that the naturalist alone is benefited by the existence of these vulgar creatures?

* See note on page 58.

Have we not also ascertained that those living beings which we were apt to regard as useless, or nearly so, are of far greater importance in the economy of creation than others that we are in the habit of tending with a fostering care?

We poison, or otherwise destroy the troublesome flies, whilst we seek, by every means that human ingenuity can devise, to multiply our stock of Bees, and are willing to devote any amount of time, labour, and expense, to save the lives of those swarms that were formerly, and are still in some cases, destroyed, in order to obtain the honey.

But we ask you, reader, to recall to mind the services rendered to us by each of these creatures, and then to say which of the two is the most essential to our existence, the Bee or the Fly?

No one will deny that the Bee is a very useful insect; to its industry we are indebted for wax and honey, which substances facilitate in many respects the practice of art, science, and domestic economy. But what injury would result to us if every hive, with its inhabitants, were swept from the face of the earth?

On the other hand, let us suppose that we had no flies to annoy us in the summer months: how should we fare in regard to health? Who would search out and clear away the carcases of animals, and protect us from the effluvia arising from their decomposition, with the same celerity and precision as do these little natural scavengers? Their very abundance, which

causes us so much discomfort during a few weeks in the year, is the beneficent provision made by the Ruler of Nature for their universal presence at a season when decomposition proceeds with the greatest activity in every direction; and wherever there are animal remains to be converted into useful food for man or beast, there we will guarantee that you may find at least *the one fly* which (with its progeny) is capable, according to a reflecting naturalist, of devouring the carcase of an ox in a shorter space of time than a lion could accomplish the same task.

And turn we to the Worm; that worthless, creeping abomination to the shallow intellect. Here we find a creature not only admirably constituted for a special purpose; but, *what is* that purpose? Why, the formation of the very soil upon which we move! of the superficial deposit whence proceeds the nutriment without which neither Fly, Bee, nor we ourselves could maintain existence!

It is indeed a fact which no naturalist will gainsay, that the principle here enunciated is not limited to these three forms of life alone, but that as a general rule all the lower animals that we are apt most to undervalue are on due consideration found to be of the greatest importance in the economy of Nature. Nor have we found these so-called ignoble creatures to be left unprovided and defenceless to take their chance in the "struggle for existence." Each is endowed by its Creator with bodily and mental attributes the most perfectly adapted to its

sphere of action; the humble Worm with its innumerable hooks to enable it to penetrate the soil in search of food; the Fly with its proboscis to secure its share of nutriment; the industrious little Bee with her pollen-baskets, her wax-pockets, and all the other requirements of her calling; and both Fly and Bee, along with their congeners, are furnished with innumerable eyes having in all probability varying ranges of vision, to guide them in search of a friendly store or warn them of the approach of winged enemies, both of their own class and amongst the feathered tribes.

It is a truth that cannot be too often nor too earnestly impressed upon our minds, whilst our attention is directed to the natural history of animals, that—

> "Not to the human race alone
> Is His paternal goodness shown;
> The tribes of earth, and sea, and air,
> Enjoy His universal care;"

for each created being has its share of love and its sphere of usefulness allotted by its Maker.

Another fact, which has been brought under our notice in a striking manner, is, that, however conversant we may imagine ourselves to be with the so-called laws of life, it is not wise to hasten to conclusions based upon our present knowledge of them; or at least to be dogmatical in the expression of our opinions.

The recent discoveries of zoologists concerning the various modes of reproduction in animals, and espe-

cially the remarkable deviation from the established law, as exemplified in the Bee, must suffice to show all thinking men that the Almighty employs a variety of means to arrive at the same end; and we cannot refrain from adding, that if the same reserve were also exercised in pronouncing upon moral, political, and religious questions, as we have recommended with respect to physiological inquiries, there would be much less acrimony and strife amongst mankind than exist at present.

And, finally, coupling our observations upon the structure and uses of these animals with our experience of their mental qualities, we are enabled to arrive at the following conclusions with respect to ourselves and our relation to the inferior intelligences, as well as to the highest Source of all intelligence.

We find that, however solicitous we may be concerning our bodily health and comfort, He has been infinitely more so.

These creatures were made to precede us in the development of Animal existence, to a great extent for our benefit; and for ages, in all probability, our Heavenly Father had wrought with perfect wisdom to prepare for us a suitable home on earth.

The lowly Worm accumulated, and still continues to construct, the surface-soil to which, each spring, we consign the seeds that yield us rich autumnal fruits.

The Fly, meanwhile, is the guardian of our health; and whilst we, ungrateful, rob the parent of existence,

her countless progeny protects us from the dire disease that menaces our life.

And then, the sensitive, industrious little Bee flies busily from flower to flower, and, fertilizing blossoms in her flight, makes gay our gardens, lawns, and meadows; and gathering honey as she sings, with this, and with her wax, supplies the means to gratify our cultivated tastes of mind and body.

But when we come to review the mental endowments that animate the lower creatures, causing them thus to operate for the common weal, as well as for our own especial benefit, and compare these with our own reasoning nature, we are led to perceive that, although we have been included in the vast scheme of Creation, and are in a natural sense allied to the animal races, whose physical and mental structure finds its culmination in ourselves, yet there has also been implanted in our perishable substance a germ of that divinity which we ourselves are capable of cultivating until it assumes more and more the image of the Almighty. Whilst even the most highly favoured of our humble associates amongst the domesticated tribes are allowed to inherit only so much of man's moral nature as his caprice sees fit to grant, or his convenience necessitates, every human being possesses the privilege of drawing near to the Eternal and Invisible Father of all, who, being perfect, is ever ready to enlighten those who search for truth and wisdom.

It must, however, be remembered that we cannot

claim this privilege as a right; but that in His overflowing beneficence, and in perfect accordance with all His vast designs, He has endowed us with these powers of will and intellect, as the means best adapted for the attainment of the ends He had in view in our creation.

That He has, moreover, in thus constituting us, guaranteed our perfect happiness, provided we faithfully exercise our heavenly prerogative, will surely need no proof, and whilst, through the contemplation of that unity of design and development everywhere visible in Creation, we are permitted to form some faint conception of the Creator, it behoves us on every favourable and fitting occasion to express to Him our gratitude, not only for having formed us in His own image, but for having fitted to our uses these and all His other Humble Creatures.

FINIS.

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